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Trace Metals and Total Nutrients in Human and Cattle Foods

By E. B. Holland and W. S. Ritchie

This information concerning the composition of various plant materials is provided because of the very general interest in the nutritional function of certain trace elements.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

TRACE METALS AND TOTAL NUTRIENTS IN HUMAN AND CATTLE FOODS

By E. B. Holland, Research Professor, and W. S. Ritchie, Professor of Chemistry

Foods have been a subject for investigation by the Massachusetts Experiment Station ever since its organization, and comprise a wide range of products. Recently the determination of trace metals, supposed to have a functional activity in assimilation and possibly some therapeutic value, has received major attention. As natural food products are in themselves responsive in assimilation and growth to seasonal, cultural, and other environmental conditions, the problem becomes somewhat involved.

Collection and Preparation of Samples

Numerous samples of fruits and vegetables were obtained from the State College and vicinity and many vegetables from the Waltham Field Station and eastern market gardeners. Similar samples were secured from other sections and in addition cereals, nuts, processed human foods, and cattle feeds. Duplicates in succeeding years served to check variability in some measure. All samples were expected to be mature, marketable products in prime condition for use, but some failed to meet these requirements. Immature and overripe products vary appreciably in proximate constituents but to a less extent in trace metals. The type and rapidity of growth are also factors influencing composition. Respiratory changes in some fruits and vegetables during transportation and storage affect composition at the expense of the carbohydrates.

The samples were culled as in household practice, washed if necessary, comminuted, and dried in an electrically heated oven in a strong current of warm air (about 50° C). Under such treatment the tissue sets quickly with a minimum of deterioration in fat and carbohydrates. Many of the early samples were pared or scraped but the practice was largely discontinued later. The dried samples were ground to a 1 mm. sieve and preserved in glass containers for subsequent analysis.

Basis of Analysis

Most fruits and vegetables contain from 80 to 96 percent of water at maturity but lose rapidly on exposure. These foods are frequently marketed fresh, frozen, canned, or dried. On the other hand, most cereal products, navy beans, nuts, oil meals, and other industrial by-products are substantially air-dry when marketed. With such a range in moisture content, dry matter offers the most equitable basis for comparison. Proximate constituents are reported in percentage and trace metals in parts per million.

As previously stated, most fruits and vegetables are high in moisture when received by the consumer in *fresh* condition but lose water on exposure in harvesting and in transportation and storage. The amount of loss will, of course, vary with the character of the product and subsequent treatment. Generally the dry matter will range from 5 to 20 percent. Comparatively few contain less than 5 percent, but others having a long ripening period or suffering undue exposure will contain more than 20 percent of dry matter. Any arbitrary percentage

derived from a single sample or a small group has little significance. For those desiring comparable data on the fresh product, the factors .05, .10, .15, and .20 may be applied to the results published for materials containing 95, 90, 85, and 80 percent of moisture.

Classification of Food Products

For comparative purposes the samples have been grouped according to the nature of the product and its use as a food. The determination of the proximate constituents was a secondary objective but serves to show to what extent substitution may be feasible. The following classification was employed. The botanical classification used is that of Albert F. Hill.[1]

- Major Fruits—large fruits such as apples and peaches
- Minor Fruits—berries
- Vegetables
  - Garden Fruits—pumpkins, squash, melons, etc.
  - String Beans
  - Peas and Shell Beans
  - Leaf and Stem—spinach, lettuce, celery, cabbage, onions, etc.
  - Root—beet, turnip, radish, carrot, potato, etc.
- Cereals, low fiber—without hulls or with hulls removed
- Cereals, high fiber—with hulls, as oats
- Nuts
- Processed Human Foods—breakfast foods
- Cattle Feeds, low protein
- Cattle Feeds, medium to high protein
- Roughage
- Kitchen Waste—fruits and vegetables
- Miscellaneous

With the elimination of water, most natural and processed foods contain from 50 to 90 percent or more of soluble or easily digested carbohydrates (sugars and starch). Exception will be noted later. Appreciable amounts of protein occur in some members of most groups. Fat is a minor constituent except in one group. Fiber is present in nearly all plant foods and tends to increase in most instances with maturity and overripe stages of growth.

The soluble ash constituents of natural foods vary with environmental conditions and feeding ability of the plant. The insoluble ash (largely silica) is due frequently to the retention of soil particles in the interstices of the leaves. When the amount exceeds 0.50 percent, the determination of trace metals may be vitiated.

Methods Employed

The following analytical methods were employed: moisture was determined by drying in a vacuum oven at 50° C to constant weight; protein (N x 6.25), by the Kjeldahl-Gunning method with salicylic acid; fat, by extraction with anhydrous ethyl ether; fiber, by the Official Method for Grain and Stock Feeds[2]; and ash, by incineration in an electric muffle below visible redness (about 500° C). By acid extraction, the crude ash was resolved into two carbon-free portions, soluble and insoluble.

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[1]Economic Botany. 1st Ed. 592 pp. McGraw-Hill Book Company. 1937.

[2]A. O. A. C. Methods of Analysis, 4th Ed. pp. 340-341. 1935.

Summary of Analyses of Human Foods and Cattle Feeds

Food Groups	Original Moisture	Range in Nutrients (Dry Matter Basis)						Range in Trace Metals (Dry Matter Basis)			
		Crude Protein	Crude Fat	Nitrogen-Free Extract	Crude Fiber	Crude Ash		Iron	Copper	Manganese	Phosphorus
						Soluble	Insoluble				
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*
Major fruits	75–90	1.0– 8.5	0.1– 2.0	84–94	1.0– 6.5	1.0– 4.5	0.00–0.04	tr. –76	2–13	tr. – 7	200– 1770
Minor fruits, berries	80–92	2.3–16.5	2.0–10.5	52–87	7.0–29.0	1.0– 5.5	0.00–0.30	10–176	4–39	11–168	590– 2880
Vegetables:											
Garden Fruits	79–97	5.0–20.0	0.5– 3.7	59–86	4.5–15.0	3.5–11.5	0.00–0.17	21– 129	4–34	tr. – 34	1270– 5630
String beans	90–93	18.0–23.0	1.0	55–63	11.5–12.0	6.5– 9.0	0.02–0.05	81– 112	10–18	14– 19	3550– 4740
Peas and shell beans	55–79	25.0–31.0	1.5	52–65	3.5– 8.5	4.0– 8.0	0.00–0.11	78– 99	8–22	8– 32	4170– 6690
Leaf and stem vegetables	81–96	5.0–40.0	0.7– 4.8	25–79	3.5–14.5	4.0–26.0	0.00–2.56	27– 617	2–34	tr. –260	1270– 9610
Root vegetables	71–96	2.5–16.5	0.1– 2.0	54–91	1.5–10.5	3.0–17.0	0.00–0.42	22– 290	5–28	tr. –156	1420– 5000
Cereals:											
Low fiber	—	9.0–21.5	0.5– 6.0	71–86	0.7– 4.5	1.0– 3.0	0.00–0.68	16– 324	1–26	tr. – 72	1640– 6160
High fiber	—	11.0–20.0	2.0– 6.0	65–69	9.0–12.0	2.0– 2.5	1.00–1.48	38– 74	12–43	20–103	3820– 4320
Nuts	—	11.0–32.0	51.0–72.0	5–17	3.5	2.0– 4.0	0.00–0.01	tr. – 46	7–22	12– 43	2590– 7520
Processed human foods	—	0.1–22.0	0.1– 6.5	71–99.5	0.1– 2.3	0.2– 3.0	0.00–0.11	2– 73	0–22	tr. – 82	tr. – 4990
Cattle feeds:											
Low protein	—	6.5–22.5	0.2–11.0	56–76.5	0.2–22.3	1.2–10.4	0.00–0.46	24– 369	2–30	tr. –167	840–16210
Medium to high protein	—	21.0–48.0	1.5–11.5	28–56	2.5–12.5	1.0– 7.6	0.10–2.36	113–1087	19–73	tr. –335	2200–11260
Roughage	—	8.0–29.5	1.5– 4.5	41–59	13.0–33.5	4.0– 9.0	0.30–5.85	210–1537	9–35	14–177	1350– 6900

Nutrients in Dry Matter

Although based on a limited number of samples, the analytical data seem to warrant the following deductions. The major fruits are notable primarily for their high carbohydrate content. The berries average considerably lower in carbohydrates and contain more protein, fat (wax), and fiber. The Rubus varieties are relatively high in crude fiber. The garden fruits, as a whole, contain more protein and ash than the fruits previously considered, with the exception of the pumpkin, winter squash, and muskmelon.

The beans and peas, in common with most leguminous crops, contain considerable protein, and some varieties of soybeans are high in fat.

The leaf and stem vegetables constitute one of the most diversified groups. Wide variations in composition occur in the same variety grown under different environmental conditions. Onions, cabbage, cauliflower, celery, and lettuce frequently contain 50 percent or more of nitrogen-free extract, and the quality, in some instances at least, appears to increase with the percentage. Onions are low in protein, while leaf greens, celery, and lettuce are fairly high in protein and ash, and asparagus in protein. Most root vegetables are high in carbohydrates, with mangels and radish containing more than average amounts of protein and ash.

The cereals of low fiber content are similar to the root vegetables in total extract, although this is more largely starch. The other cereals reflect a higher fiber content. The nuts, including the peanut, are unlike any other group and contain a very high percentage of fat.

Processed human foods resemble the cereals from which many are derived. The cattle feeds are industrial by-products and vary with the original substances and subsequent treatment.

Forage plants, fed green or dry to farm animals, are naturally high in fiber and ash and when cut early contain considerable protein, especially in the case of leguminous forage.

Trace Metals in Dry Matter

Innumerable determinations of the more prominent inorganic elements in plant products have been reported in the literature during the past few decades. These results were obtained largely by the gravimetric methods then in vogue. More recently, with the introduction of the so-called microchemical or colorimetric methods, the determination of the rarer mineral elements has received considerable impetus. The results herein reported were determined exclusively by colorimetric methods based on visual readings with a Duboscq Comparator. In the preparation of solutions, wet combustion was found more serviceable, more rapid, less subject to contamination, and of wider application than dry combustion when many samples are involved. Dry combustion was used for the determination of zinc, but later investigation has shown that with a preliminary treatment the regular sulfuric acid solution can be employed. Iron was determined by the thiocyanate reaction; copper, by sodium diethyl dithiocarbamate reagent and extraction with carbon tetrachloride; zinc, by diphenylthiocarbazone reagent and extraction with carbon tetrachloride; manganese, by periodate oxidation; and phosphorus, as molybdenum blue. The methods are presented in some detail on pages 24-31.

Many practitioners and dietitians assume that foodstuffs containing appreciable amounts of these elements may serve as curative or at least preventive agents in cases of malnutrition and functional derangements. Furthermore some

workers believe that these elements as components of plant and animal tissue are more efficient than drugs and unquestionably safer to employ.

The factors that affect synthesis of proteins, fat, carbohydrates, and fiber may play a somewhat similar role in the assimilation and utilization of ash and ash constituents as all groups are more or less interdependent; but the available supply of soil nutrients appears to be more of a limiting factor in ash assimilation than selective absorption.

Distribution of Ash Constituents

The soluble ash is a measure of plant assimilation but not of the distribution of its constituents. As previously stated, seasonal and environmental conditions, soil, fertilization, cultural treatment, etc., and the feeding ability of the plant are all factors, but to a considerable extent uncontrollable. The garden fruits exceed the major and minor fruits in ash content, followed by root and leaf and stem vegetables. The remaining groups except some cattle feeds and roughage are low in ash.

Iron is the most abundant of the trace metals determined and in some instances seems to parallel the soluble ash. The amount increased from fruits and cereals to root vegetables, leaf and stem vegetables, cattle feeds, and roughage.

Copper is apparently not present to any great extent in most soils or at least is not available, as the amount assimilated by plants varied from 4 to 40 parts per million.

The amount of manganese in foods exceeds copper. It is of similar distribution but more variable. Two grams of material in many instances will yield only a bare trace of manganic acid.

A few results on zinc are also reported. These were determined by the original method and may be slightly low in some instances because of incomplete recovery of the zinc from the ash. The amount of zinc in most samples exceeds that of copper and occasionally even that of manganese. The results are inadequate, however, for any generalization.

The amount of phosphorus in most natural and processed foods is relatively high as compared with the metals so far reported, generally ranging from 200 to 16,000 parts per million, the main portion of which occurs in organic combination with the protein and ether-soluble bodies. The phosphorus content appears to increase from the major fruits to the minor fruits, root vegetables, cereals, roughage, leaf and stem vegetables, and cattle feeds.

The analyses show that trace metals are subject to a greater range than the nutrients (proximate analysis). The differences in composition between members of the same group and even between samples of the same variety are so large that a generalization or trend is about all that is permissible.

Analyses of Human Foods and Cattle Feeds

Food Product	Sample No.	Original Moisture	Crude Protein	Crude Fat	Nitrogen Free Extract	Crude Fiber	Crude Ash Soluble	Crude Ash Insoluble	Fe	Cu	Mn	Zn	Ca	P
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*Percent*	*p.p.m*
Major Fruits														
Banana, *Musa paradisiaca* L. subsp. *sapientum* (L.) O. Ktze.														
....	464	74.80	3.40	0.41	91.60	0.98	3.57	0.04	34	11	Trace	10		1,150
....	465		3.51	0.61	91.85	0.85	3.15	0.03	23	11	Trace	12	0.010	1,170
Plum, *Prunus domestica* L.														
....	58	84.60	3.53	1.39	89.19	3.71	2.18	0.00	55	6	3			710
Grand Duchess	371	81.10	2.87	0.92	91.73	2.09	2.38	0.01	34	7	Trace		0.047	710
Peach, *Prunus Persica* (L.) Sieb. & Zucc.														
Freestone, pared	57	87.60	5.71	0.54	86.59	3.62	3.54	0.00	35	13	7			1,210
Freestone, pared	376	90.00	7.09	0.27	84.38	3.74	4.52	0.00	30	4	Trace		0.043	1,770
Sour Cherry, *Prunus Cerasus* L.														
Early Richmond	315	85.10	8.54	0.17	86.48	1.27	3.52	0.02	36	12	Trace		0.093	1,620
Sweet Cherry, *Prunus avium* L.														
Stark Gold	327	82.20	1.37	0.14	93.72	1.55	3.21	0.01	24	10	Trace			1,140
Pear, *Pyrus communis* L.														
Clapp's Favorite, cored and pared	56	86.50	3.69	0 78	86.97	6.49	2.05	0.02	76	13	2		0.082	820
Apple, *Pyrus Malus* L.														
Baldwin, cored	727	85.00	1.60	1.62	89.46	5.62	1.70	0.00	35	12	None		0.024	790
McIntosh, cored	728	86.40	1.34	1.96	90.68	4.89	1.12	0.01	11	2	Trace		0.043	510
Wealthy, cored and pared	55	87.40	0.98	2.00	90.55	4.61	1.84	0.02	54	9	None			630
Baldwin, cored and pared	237	85.70	1.11	0.73	92.78	4.05	1.32	0.01	21	5	Trace			770
McIntosh, cored and pared	235	85.40	1.27	0.86	93.09	3.61	1.15	0.02	34	5	Trace			690
Grapefruit, *Citrus maxima* (Burm.) Merr. var. *uvacarpa* Merr. & Lee														
Florida raised, juice	630	88.80	—	—	—	—	3.56	0.00	19	9	Trace			1,420
Orange, *Citrus sinensis* (L.) Osbeck.														
California raised, juice	628	85.00	—	—	—	—	3.14	0.00	14	9	Trace			1,370

Food Product	Sample No.	Original Moisture	Crude Protein	Crude Fat	Nitrogen Free Extract	Crude Fiber	Crude Ash Soluble	Crude Ash Insoluble	Fe	Cu	Mn	Zn	Ca	P
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*Percent*	*p.p.m*
Major Fruits—Cont.														
Grape, *Vitis Labrusca* L.														
Delaware, juice	508	79.80	—	—	—	—	2.30	—	13	6	Trace			200
Niagara, juice, hand pressed	506	84.40	—	—	—	—	1.51	—	Trace	5	Trace			300
Niagara, juice	507	84.70	—	—	—	—	2.61	—	48	7	Trace			320
Worden, juice	509	84.80	—	—	—	—	2.38	—	37	8	Trace			260
Minor Fruits, Berries														
Currant, *Ribes sativum* Syme.														
.....	14	—	—	—	—	—	5.38	0.04	112	29	20			1,660
.....	328	82.80	10.16	4.15	73.14	8.21	4.23	0.11	97	39	31		0.163	2,440
Strawberry, *Fragaria chiloensis* (L.) Duchesne.														
.....	61	90.80	6.07	3.85	74.90	10.27	4.83	0.08	107	8	168			2,120
.....	310	91.90	7.08	3.27	73.76	10.75	5.01	0.13	88	9	108			1,830
.....	451	90.70	8.82	3.21	74.52	8.39	4.90	0.16	125	12	43	18		2,370
.....	452	—	8.56	3.17	73.29	9.84	5.08	0.06	85	21	62	18		2,880
.....	679	90.30	5.91	4.40	75.64	9.18	4.72	0.15	54	5	25		0.202	2,800
Average	...	90.90	7.29	3.58	74.42	9.69	4.91	0.11	92	11	81	18		2,400
Blackcap, *Rubus occidentalis* L.														
.....	342	82.90	7.94	6.46	61.98	20.20	3.12	0.30	176	14	71		0.209	1,830
Red Raspberry, *Rubus Idaeus* L.														
.....	15	—	7.10	5.39	66.96	17.27	3.28	0.00	92	22	88			1,450
Ten varieties	60	86.00	8.45	4.68	59.52	23.82	3.44	0.09	125	15	85		0.191	1,740
Blackberry, *Rubus alleghaniensis* Porter.														
.....	12	—	9.60	5.26	52.45	29.16	3.52	0.01	64	25	34			1,490
.....	343	86.00	16.56	4.28	53.14	21.61	4.38	0.03	53	7	35		0.163	2,170
Blueberry, *Vaccinium corymbosum* L.														
.....	13	—	3.06	1.97	86.57	6.79	1.61	0.00	41	13	43			730

....	59	80.30	3.59	3.90	82.34	8.68	1.47	0.02	62	23	54		870
....	344	—	3.66	4.28	83.07	7.79	1.19	0 01	46	13	20	0.070	2,180
Average..........	...	80.30	3.44	3.38	84.00	7.75	1.42	0.01	50	16	39		1,260
Cranberry, *Vaccinium macrocarpon* Ait.													
Early Black..........	239	87.30	3.34	6.74	78.45	10.09	1.35	0.03	45	8	68		780
Early Black..........	692	87.70	2.80	9.08	75.77	11.09	1.26	0.00	10	4	11	0.103	590
Howes..........	240	86.40	2.31	5.27	80.71	10.45	1.23	0.03	43	8	61		630
Howes..........	729	87.30	3.10	10.62	71.22	13.84	1.21	0.01	35	6	26	0.088	740
Average..........	...	87.20	2.89	7.93	76.53	11.37	1.26	0.02	33	7	42		690
Vegetables, Garden Fruits													
Eggplant, *Solanum Melongena* L.													
Seeded..........	80	91.90	14.63	2.09	60.47	14.73	7.91	0.17	89	10	8		2,390
Tomato, *Lycopersicon esculentum* Mill.													
Skinned..........	88	93.70	18.94	3.31	63.99	5.20	8.55	0.01	91	17	15		4,380
Skinned..........	370	94.90	17.18	3.70	64.37	5.47	9.25	0.03	62	14	18		4,350
Greenhouse raised, Fe applied......	671	94 00	15.07	2.16	63.45	9.55	9.76	0.01	54	13	10		4,740
Cu applied......	672	93.20	15.17	2.17	63.72	9.47	9.46	0.01	41	12	16		4,650
Mn applied.....	673	93.60	14.69	2.44	63.84	9.20	9.82	0.01	40	11	8		4,580
I applied.....	674	93.80	15.23	2.21	62.92	9.50	10.14	0.00	50	7	Trace		5,090
Check..........	675	93.20	14.76	1.95	63.92	9.71	9.65	0.01	47	9	Sl. Tr.	0.143	5,000
Fe applied.....	743	—	16.19	3.62	60.72	10.06	9.41	0.00	68	16	8		5,120
Cu applied.....	744	—	18.42	3.25	59.60	9.76	8.97	0 00	53	17	16		4,530
Mn applied.....	745	—	18.44	3.22	58.86	10.01	9.47	0.00	65	12	31		4,720
I applied.....	746	—	16.52	3.13	61.08	10.22	9.05	0.00	70	16	22		5,010
Check..........	747	—	17.15	3.11	60.12	10.43	9.19	0 00	52	16	21	0 110	4,580
Average..........	...	93.80	16.48	2.86	62.21	9.05	9.39	0.01	58	13	14		4,730
Sweet Pepper, *Capsicum frutescens* L. var. *grossum* (L.) Bailey.													
California Wonder, seeded..........	83	93.50	17.57	1.51	65.91	11.09	3.90	0.02	129	34	15		4,160
....	373	93.60	18.58	1.28	63.54	9 69	6.89	0.02	86	18	28	0.126	2,140
Pumpkin, *Cucurbita Pepo* L.													
....	382	89.50	6.36	1.04	76.00	9.96	6.64	0.00	43	10	11	0.200	1,500
Summer Squash, *Cucurbita Pepo* L.													
Pared..........	86	95.30	19.83	1.60	60.26	8.66	9.63	0.02	77	15	34		5,630
....	339	95.10	18.37	1.62	61.20	7.72	11.03	0 06	79	11	20	0.673	4,590

Analyses of Human Foods and Cattle Feeds — Cont.

Food Product	Sample No.	Original Moisture	Crude Protein	Crude Fat	Nitrogen Free Extract	Crude Fiber	Crude Ash Soluble	Crude Ash Insoluble	Fe	Cu	Mn	Zn	Ca	P
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*Percent*	*p.p.m*
Vegetables, Garden Fruits.—Cont.														
Winter Squash, *Cucurbita maxima* Duchesne.														
Blue Hubbard, pared, seeded.......	252	79.40	4.82	0.42	86.45	4.72	3.57	0.02	31	6	Trace		0.059	1,270
Cucumber, *Cucumis sativus* L.														
Pared..........................	367	97.00	15.12	1.03	67.95	7.09	8.78	0.03	90	17	11			5,090
....	635	95.90	14.07	1.25	70.10	5.46	9.09	0.03	21	4	Trace		0.196	4,220
Seed Cucumber, pared............	79	95.50	23.90	1.33	50.81	12.23	11.64	0.09	121	24	13			10,690
Muskmelon, *Cucumis Melo* L.														
Pared, seeded....................	368	92.00	5.61	0.45	80.21	4.55	9.07	0.11	81	12	Trace		0.142	2,230
Vegetables, String Beans														
Snap Bean, *Phaseolus vulgaris* L.														
Wax...........................	1	92.60	23.02	1.16	55.05	12.00	8.72	0.05	102	16	14			3,760
Wax...........................	62	92.10	22.17	0.93	55.63	12.11	9.11	0.05	112	10	17			4,740
Wax...........................	345	90.20	18.29	0.76	62.82	11.49	6.62	0.02	81	18	19		0.450	3,550
Average....................	...	91.60	21.16	0.95	57.83	11.87	8.15	0.04	98	15	17			4,020
Vegetables, Peas and Shell Beans														
Pea, *Pisum sativum* L.														
....	82	78.70	29.52	1.45	52.41	8.45	8.06	0.11	87	22	9		0.073	6,160
....	453	77.70	30.89	1.65	55.48	7.94	4.01	0.03	99	8	32	79		6,690
Bean, *Phaseolus vulgaris* L.														
Navy or pea.....................	667	—	26.23	1.69	63.68	4.60	3.79	0.01	78	8	8		0.205	4,170
Shell...........................	63	55.30	25.67	1.42	65.02	3.68	4.20	0.01	89	19	10			5,910
Lima Bean, *Phaseolus lunatus* L.														
....	375	75.30	25.20	1.60	61.51	5.83	5.86	0.00	85	8	26		0.112	4,620
Average....................	...	65.30	25.70	1.57	63.40	4.70	4.62	0.01	84	12	15			4,900
Soybean, *Glycine Soja* (L.) Sieb. & Zucc.														
Dunfield.........................	819	—	35.09	22.49	31.56	5.85	5.01	0.00	114	19	7			6,770

Vegetables, Leaf and Stem

Onion, *Allium Cepa* L.													
Yellow Globe, peeled	5	90.30	15.08	1.11	72.85	5.69	5.27	0.00	68	25	14			3,410
	6	91.00	16.14	1.14	70.80	6.03	5.89	0.00	70	32	15		0.210	3,000
	7	90.60	16.12	0.90	72.07	5.56	5.33	0.02	60	18	12			3,500
	8	86.00	16.24	0.80	73.10	5.32	4.52	0.02	78	21	10			2,180
	9	86.80	11.48	0.93	77.80	5.27	4.46	0.06	53	19	16			2,500
	101	—	19.51	1.21	67.08	6.19	6.00	0.01	51	7	28			3,850
	102	—	19.27	1.31	66.99	6.55	5.87	0.01	49	7	29			3,990
Danvers Yellow Globe, peeled	251	87.10	13.67	0.57	77.45	3.81	4.45	0.05	49	7	13			3,410
Average	...	—	15.94	0.99	72.26	5.55	5.22	0.04	60	17	17			3,230
Ebenezer Japanese, peeled, Fe applied	347	—	11.06	0.75	79.18	5.01	3.95	0.05	51	5	18			1,480
Cu applied	348	—	11.07	1.07	78.28	5.52	4.02	0.04	38	6	17			1,460
Mn applied	349	—	10.70	1.00	79.29	5.15	3.83	0.03	45	5	16			1,410
I applied	350	—	10.70	0.80	79.47	5.17	3.86	0.00	36	7	14			1,630
Check	351	86.20	11.36	0.74	78.42	5.38	4.09	0.01	43	10	16			1,670
Fe applied	478	—	14.99	0.72	76.00	3.66	4.59	0.04	85	5	13	27		3,470
Cu applied	479	—	15.88	0.73	74.96	3.67	4.73	0.03	70	9	13	28		3,680
Mn applied	480	—	15.19	0.76	75.61	3.61	4.80	0.03	53	5	13	31		3,430
I applied	481	—	15.07	0.70	75.95	3.55	4.71	0.02	60	5	12	34		3,520
Check	482	—	15.90	0.74	74.92	3.56	4.87	0.01	45	10	12	38	0.202	3,610
Average	...	86.20	13.19	0.80	77.21	4.43	4.34	0.03	53	7	14	32		2,536
Asparagus, *Asparagus officinalis* L.													
	306	93.40	39.18	2.36	39.22	9.81	9.36	0.07	111	14	27			8,520
	450	92.80	36.05	3.12	42.05	9.99	8.69	0.10	145	13	48	76	0.262	8,060
	669	92.60	31.43	2.92	47.41	10.08	8.00	0.16	100	4	18		0.217	7,620
Average	...	92.90	35.55	2.80	42.90	9.96	8.68	0.11	119	10	31			8,070
Rhubarb, *Rheum Rhaponticum* L.													
Skinned	85	94.40	9.58	1.05	62.78	12.15	14.40	0.04	191	13	32			3,560
	311	93.80	5.34	0.99	65.51	10.83	17.31	0.02	27	8	Trace		1.891	2,970
	666	—	13.01	1.36	59.62	14.41	11.57	0.03	27	6	Trace		0.558	4,750
Average	...	94.10	9.31	1.13	62.64	12.46	14.43	0.03	82	9	11			3,430
Beet, *Beta vulgaris* L.													
Greens	64	92.40	29.65	1.80	35.10	8.74	22.15	2.56	946	15	36			4,570

Food Product	Sample No.	Original Moisture	Crude Protein	Crude Fat	Nitrogen Free Extract	Crude Fiber	Crude Ash Soluble	Crude Ash Insoluble	Fe	Cu	Mn	Zn	Ca	P
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*Percent*	*p.p.m*
Vegetables, Leaf and Stem—Cont.														
Swiss Chard, *Beta vulgaris* L. var. *Cicla* L.														
....	3	91.10	23.86	1.69	46.37	11.40	16.61	0.07	148	19	33			3,580
Fordhook Giant..................	87	92.10	26.91	2.76	39.47	10.18	20.31	0.37	273	23	43		0.712	4,260
Spinach, *Spinacia oleracea* L.														
....	90	—	34.05	2.68	31.86	8.41	21.97	1.03	556	21	160			6,400
....	91	—	34.28	2.83	32.19	8.38	21.56	0.76	488	11	148			6,160
....	92	—	35.41	—	—	8.66	22.16	1.06	569	11	127			6,290
Texas raised.....................	633	90.70	31.26	3.21	34.74	7.79	22.65	0.35	384	5	130		2.494	3,190
Massachusetts raised.............	693	91.10	37.36	3.03	24.86	8.07	25.66	1.02	580	10	27		1.034	9,480
Average..........................	...	90.90	34.24	2.94	30.91	8.16	22.96	0.79	515	12	118			6.100
Burpee's Victoria, gritty, Fe applied	316	—	31.68	3.33	36.10	8.29	18.57	2.03	1109	11	94			2,890
Cu applied	317	—	31.12	3.64	36.36	8.50	18.58	1.80	1080	24	90			2,980
Mn applied	318	—	32.28	2.96	33.94	8.26	19.59	2.97	1258	14	127			3,020
I applied	319	—	32.93	2.87	34.09	9.00	19.13	1.98	1173	15	122			2,900
Check.....	320	86.90	31.27	2.92	35.69	8.56	19.56	2.00	1141	14	133			2,670
Average..........................	...	—	31.86	3.14	35.23	8.52	19.09	2.16	1152	16	113			2.890
New Zealand Spinach, *Tetragonia expansa* Thumb.														
Too mature.......................	11	92.50	30.79	2.18	34.34	9.44	23.16	0.09	119	29	93		0.914	3,530
....	81	92.90	28.63	3.54	32.98	8.39	25.91	0.55	405	19	71		0.971	6,530
Cabbage, *Brassica oleracea* L. var. *capitata* L.														
....	2	93.60	22.72	1.22	52.93	11.66	11.45	0.02	64	8	14			5,410
....	66	93.10	15.95	1.35	65.00	9.49	8.19	0.02	82	5	19			2,700
....	688	92.80	22.40	1.22	57.40	9.39	9.58	0.01	44	3	Trace		0.747	5,160
....	689	92.70	23.52	1.38	55.67	10.79	8.63	0.01	71	2	23			3,900
....	698	92.50	26.31	0.92	53.44	9.60	9.73	0.00	69	12	11		0.935	3,920
....	699	92.60	18.45	1.06	61.97	9.53	8.97	0.02	42	6	Trace			3,850
Average..........................	...	92.90	21.56	1.19	57.73	10.08	9.43	0.01	62	6	11			4,160

Cauliflower, *Brassica oleracea* L. var. *botrytis* L.														
....	69	92.20	24.38	1.51	51.05	12.72	10.30	0.04	247	11	16			5,610
....	383	92.80	30.76	1.49	45.11	12.45	10.17	0.02	94	12	25		0.301	5,860
Broccoli, *Brassica oleracea* L. var. *botrytis* L.														
....	848	—	40.59	3.38	36.88	10.52	8.63	0.00	100	5	24		0.388	7,500
Parsley, *Petroselinum hortense* Hoffm.														
Moss curled	244	80.50	23.54	3.35	49.27	8.46	13.60	1.78	600	13	42			3,970
Celery, *Apium graveolens* L.														
Giant Pascal	241	94.20	19.58	0.77	59.78	8.20	11.58	0.09	73	23	Trace			6,470
....	591	—	25.08	1.12	47.59	9.23	16.81	0.17	104	13	19			7,260
....	730	93.40	19.62	0.94	54.45	9.92	15.01	0.06	80	13	24		0.628	6,680
....	801	—	19.02	1.07	55.89	10.11	13.88	0.03	50	16	11			5,300
....	681	95.30	17.45	1.16	48.33	13.49	19.53	0.04	53	34	Trace		0.640	6,810
....	682	95.60	23.36	1.22	40.01	13.73	21.54	0.14	72	17	3			7,470
....	695	94.80	23.29	1.18	46.31	12.31	16.84	0.07	484	14	Trace		0.669	6,800
Average	...	94.70	21.06	1.06	50.34	11.00	16.46	0.08	131	19	8			6,680
Dandelion, *Taraxacum officinale* Weber.														
....	665	86.30	22.98	4.81	48.18	11.11	11.67	1.25	617	17	53			4,390
Lettuce, *Lactuca sativa* L. var. *capitata* Hort.														
Boston type	4	94.40	26.32	3.59	42.23	10.59	16.91	0.36	272	18	28		1.222	5,930
Iceberg, Arizona	634	96.00	26.82	2.11	49.91	10.19	10.85	0.12	142	12	31		0.352	5,670
Iceberg, California	733	95.90	18.05	2.61	57.93	11.53	9.80	0.08	84	11	8		0.379	5,240
New York No 12, Fe applied	322	—	18.80	3.73	58.24	9.65	9.01	0.57	289	8	50			1,920
Cu applied	323	—	17.86	3.54	60.33	9.75	8.06	0.46	243	15	46			2,090
Mn applied	324	—	17.64	2.24	61.10	10.72	7.95	0.35	220	11	57			2,390
I applied	325	—	18.28	2.73	60.31	9.91	8.37	0.40	238	11	52			2,030
Check	326	95.50	18.21	3.12	59.21	10.63	8.36	0.47	239	6	47		0.500	1,980
New York No. 12, poorly headed,														
Fe applied	468	—	21.58	4.41	51.82	9.77	11.95	0.47	476	8	75	41		1,460
Cu applied	469	—	20.19	4.50	53.36	9.77	11.74	0.44	366	12	64	40		1,550
Mn applied	470	—	24.08	4.64	48.82	9.28	12.73	0.45	517	8	104	48		1,750
I applied	471	—	26.74	4.60	43.91	9.16	15.08	0.51	526	4	125	44		1,340
Check	472	—	26.29	4.10	45.10	9.39	14.66	0.46	507	4	95	43		1,270
Average	...	95.50	21.60	3.53	53.25	10.03	11.19	0.40	317	9	60	43		2,660

ANALYSES OF HUMAN FOODS AND CATTLE FEEDS — Cont.

Food Product	Sample No.	Original Moisture	Crude Protein	Crude Fat	Nitrogen Free Extract	Crude Fiber	Crude Ash Soluble	Crude Ash Insoluble	Fe	Cu	Mn	Zn	Ca	P
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*Percent*	*p.p.m*
Vegetables Leaf and Stem—Cont.														
Lettuce, Cont.														
Greenhouse raised, Fe applied......	621	94.20	33.63	3.64	32.84	9.94	19.57	0.38	227	23	127			8,450
Cu applied......	622	94.20	33.91	3.65	32.39	10.06	19.68	0.31	229	27	209			8,650
Mn applied......	623	94.10	33.92	3.78	31.24	10.18	20.37	0.51	257	24	260			9,350
I applied......	624	94.50	34.30	3.79	32.34	9.75	19.59	0.23	175	21	132			9,610
Check..........	625	93.90	33.87	3.80	32.25	9.81	19.97	0.30	182	22	219			8,840
Average..........................		94.20	33.93	3.73	32.21	9.95	19.84	0.34	214	23	189			8,980
Vegetables Root														
Beet, *Beta vulgaris* L.														
Pared..........................	65	88.60	13.42	0.43	71.95	6.02	8.18	0.00	92	9	18			3,330
....	694	89.50	16.57	0.47	65.63	7.32	9.98	0.03	71	6	Trace		0.154	4,180
....	697	84.70	13.87	0.25	72.67	5.47	7.73	0.01	52	13	9		0.093	2 830
Boston Crosby or Early Wonder, scraped,														
Fe applied..............	352	—	7.74	0.50	81.86	5.19	4.69	0.02	70	28	49			1,600
Cu applied..............	353	—	8.65	0.49	80.92	5.20	4.73	0.01	79	9	57			1,970
Mn applied..............	354	—	7.55	0.38	82.27	5.05	4.74	0.01	71	10	57			2,120
I applied..............	355	—	8.00	0.30	81.79	5.07	4.81	0.03	69	14	56			1,760
Check..............	356	81.70	7.75	0.39	81.98	5.22	4.62	0.04	70	11	56			1,840
Boston Crosby or Early Wonder,														
Fe applied..............	483	—	5.55	0.44	83.30	5.99	4.34	0.38	290	10	119	40		2,260
Cu applied..............	484	—	5.92	0.41	83.50	5.67	4.23	0.27	182	22	134	44		2,260
Mn applied..............	485	—	5.98	0.45	83.35	5.71	4.26	0.25	212	12	142	37		2,470
I applied..............	486	—	5.70	0.42	83.81	5.77	4.08	0.22	210	9	156	53		2,000
Check..................	487	—	5.68	0.45	83.68	5.64	4.25	0.30	243	10	126	44		2,370
Average....................	...	86.10	8.65	0.41	79.75	5.64	5.43	0.12	132	12	75	44		2,380
Mangels, *Beta vulgaris* L.														
....	29	94.30	16.38	0.66	57.67	10.28	14.59	0.42	283	18	33		0.208	2,870

Rutabaga, *Brassica Napobrassica* (L.) Mill.														
Canada Gem	201	89.20	11.19	0.93	73.21	8.51	6.15	0.01	78	6	18			3,010
Purple Top	10	89.70	5.85	0.82	81.75	7.48	4.07	0.03	67	16	24			2,320
Purple Top, composite of 3	200	88.20	10.09	0.99	74.62	8.35	5.92	0.03	69	12	13			2,870
....	803	—	10.67	0.89	74.21	8.66	5.51	0.06	55	6	14		0.290	2,760
White Cape	203	89.60	11.52	0.87	73.98	7.54	6.07	0.02	65	8	10			4,110
White Cape, composite of 7	804	—	10.44	0.96	74.01	8.83	5.72	0.04	54	5	18		0.298	3,070
Average	...	89.20	9.96	0.91	75.30	8.23	5.57	0.03	65	9	16			3,020
Turnip, *Brassica Rapa* L.														
Pared	89	91.00	10.29	0.85	69.58	9.63	9.61	0.04	96	15	13			4,600
Composite of 14	192	90.80	4.71	1.17	78.29	10.20	5.59	0.04	61	7	Trace			3,970
Radish, *Raphanus sativus* L.														
....	84	95.70	16.77	1.01	54.34	10.68	17.10	0.10	186	10	11		0.621	5,000
Carrot, *Daucus Carota* L.														
Scraped	67	89.20	8.02	1.13	73.64	8.38	8.83	0.00	75	8	9			4,320
....	690	86.10	9.87	1.98	73.73	7.93	6.48	0.01	29	7	15		0.327	3,410
....	691	89.50	10.68	1.34	70.54	8.36	9.06	0.02	37	12	64			3,690
....	700	88.70	9.86	1.05	73.08	8.08	7.91	0.02	54	8	10		0.249	3,520
Chantenay or Model, Fe applied	362	—	7.84	1.08	79.17	6.17	5.69	0.05	59	12	25			1,480
Cu applied	363	—	7.05	0.96	80.81	5.75	5.41	0.02	52	12	26			1,420
Mn applied	364	—	7.81	1.05	79.83	5.83	5.46	0.02	49	8	27			1,490
I applied	365	—	8.52	0.96	78.49	6.05	5.95	0.03	52	11	28			1,470
Check	366	79.20	8.12	0.75	79.02	6.07	5.97	0.07	65	12	29			1,460
Fe applied	493	—	6.11	0.96	79.26	7.83	5.79	0.05	217	12	22	12		2,180
Fe and S applied	494	—	5.99	0.85	79.62	7.55	5.90	0.09	171	14	56	11		2,260
Cu applied	495	—	6.38	0.98	78.86	7.69	6.01	0.08	144	10	20			2,250
Mn applied	496	—	6.28	0.98	79.27	7.62	5.79	0.06	127	11	16			2,340
I applied	497	—	6.54	0.90	78.20	7.92	6.36	0.08	141	7	26			2,160
Check	498	—	6.45	0.90	78.56	7.80	6.21	0.08	125	7	34			1,950
Average	...	86.50	7.70	1.06	77.47	7.27	6.46	0.04	94	10	37			2,360
Parsnip, *Pastinaca sativa* L.														
Scraped	253	78.80	8.01	2.14	78.29	5.51	6.03	0.02	38	8	Trace		0.213	4,650
Sweet Potato, *Ipomoea Batatas* (L.) Poir.														
Pared	249	70.70	2.59	0.18	91.27	2.68	3.26	0.02	22	8	19			1,450

Food Product	Sample No.	Original Moisture	Crude Protein	Crude Fat	Nitrogen Free Extract	Crude Fiber	Crude Ash Soluble	Crude Ash Insoluble	Fe	Cu	Mn	Zn	Ca	P
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	p.p.m.	p.p.m.	p.p.m.	p.p.m.	Percent	p.p.m
Vegetables Root—Cont.														
Potato, *Solanum tuberosum* L.														
Green Mountain	734	76.90	12.49	0.25	82.08	1.76	3.41	0.01	29	13	None			2,300
	735	76.20	12.57	0.23	81.97	1.68	3.52	0.03	34	13	None		0.029	2,320
Irish Cobbler	736	77.70	12.79	0.21	81.60	1.74	3.65	0.01	50	14	Sl. Tr.		0.036	2,240
Rural Russet	737	76.00	14.55	0.39	78.87	2.20	3.96	0.01	48	11	Sl. Tr.			3,150
Average	...	76.70	13.10	0.27	81.13	1.85	3.64	0.01	40	13	—			2,500
Green Mountain, pared	247	76.40	9.58	0.11	84.88	1.35	4.05	0.03	35	10	Trace			2,190
Irish Cobbler, pared	245	80.40	13.34	0.21	80.59	1.40	4.45	0.01	44	12	12			2,830
Cereals Low Fiber														
Corn, *Zea Mays* L.														
Argentine	513	—	10.65	5.30	80.56	1.85	1.61	0.03	324	26	13			3,660
Dent, var. *indentata* (Stuart.) Bailey.														
Yellow	460	—	10.17	4.85	81.71	1.76	1.50	0.01	47	5	5	28	0.003	3,250
Yellow, Argo Ensilage	461	—	9.92	4.99	81.89	1.88	1.31	0.01	40	15	6	22		2,910
White, Red Cob	458	—	10.30	4.42	82.04	1.81	1.40	0.03	44	7	18	27	0.003	3,070
White, Johnson County Ensilage	459	—	11.10	4.86	80.75	1.86	1.40	0.03	44	9	5	21		3,140
Average	...	—	10.37	4.78	81.60	1.83	1.40	0.02	44	9	9	25		3,090
Flint, var. *indurata* (Stuart.) Bailey.														
Yellow, Golden Nugget	463	—	9.00	5.14	82.76	1.55	1.54	0.01	31	6	5	29	0.003	3,370
White, Sanford White	462	—	11.42	5.06	80.75	1.38	1.38	0.01	48	7	6	34	0.002	3,170
Popcorn, var. *praecox* Bonaf.														
Bear's Foot	657	—	11.68	5.08	79.78	1.84	1.62	0.00	16	4	Trace			3,940
Black	656	—	9.96	5.73	80.98	1.97	1.36	0.00	35	1	Sl. Tr.			2,960
Sweet Corn, var. *rugosa* Bonaf.														
Cut from cob	70	76.60	14.91	5.12	75.09	1.80	3.08	0.00	53	6	Trace		0.005	4,490
Cut from cob, composite of 8	413	—	13.05	5.28	76.99	1.80	2.86	0.02	48	4	6			4,270

Milo Maize, ***Sorghum vulgare*** **Pers. var.** ***subglabrescens*** **(Steud.) A. F. Hill**														
Dwarf Yellow....................	664	—	12.05	3.19	81.53	1.66	1.54	0.03	45	2	12			2,930
White Kafir, *Sorghum vulgare* Pers. var. *cernuum* (Ard.) Fiori & Paoli.														
Black Hull......................	663	—	14.04	3.57	78.93	1.75	1.66	0.05	55	4	Trace			3,450
Wild Rice, *Zizania aquatica* L. var. *angustifolia* Hitchc.														
....	839	—	13.85	0.65	83.51	0.72	1.19	0.08	46	4	4			2,990
Brown Rice, *Oryza sativa* L.														
....	838	—	9.36	2.56	86.18	0.73	1.12	0.05	25	5	5		0.006	2,800
Wheat, *Triticum aestivum* L.														
Spring..........................	457	—	18.82	2.20	74.69	2.54	1.72	0.03	69	15	61	37		3 700
Spring, raised in Osser, Minn. 53 lb..	701	—	17.31	2.14	75.02	3.11	2.40	0.02	35	9	72		0.048	6,160
Winter, raised in Osser, Minn. 58 lb.	704	—	14.66	1.75	78.54	2.95	2.08	0.02	49	1	58		0.039	5,110
Soft............................	505	—	11.84	2.05	82.07	2.13	1.88	0.03	78	11	Trace			3,330
Durum Wheat, *Triticum durum* Desf.														
No. 3 Hard Amber................	658	—	21.48	2.31	71.08	3.04	2.06	0.03	53	9	32			4,820
Rye, ***Secale cereale*** **L.**														
Seed rye, raised in New York.......	466	—	13.16	1.69	80.96	2.01	2.07	0.11	121	11	29	47	0.044	1,820
....	467	—	14.42	1.68	80.84	1.93	1.91	0.02	65	5	16	36		1,640
Barley, *Hordeum vulgare* L.														
....	820	—	16.74	2.31	73.77	4.48	2.02	0.68	57	15	7		0.048	4,630
Cereals High Fiber														
Japanese Millet, *Echinochloa frumentacea* (Roxb.) Link.														
....	655	—	11.21	6.32	67.82	11.62	1.97	1.06	38	24	93			3,870
Oat, *Avena sativa* L.														
....	24	—	13.89	4.73	68.80	9.16	1.94	1.48	74	12	20		0.043	3,820
Emmer, *Triticum dicoccum* Schrank.														
White spring....................	670	—	19.70	1.96	65.05	9.79	2.52	0.98	60	43	103			4,320
Nuts														
English Walnut, *Juglans regia* L.														
....	608	—	15.79	72.01	6.76	3.57	1.87	0.00	29	14	19			3,640
Pecan, *Carya Pecan* (Marsh.) Eng. & Graeb.														
....	607	—	11 07	65.43	17.28	3.37	1.85	0.00	26	10	43			2,590

ANALYSES OF HUMAN FOODS AND CATTLE FEEDS — Cont.

Food Product	Sample No.	Original Moisture	Crude Protein	Crude Fat	Nitrogen Free Extract	Crude Fiber	Crude Ash Soluble	Crude Ash Insoluble	Fe	Cu	Mn	Zn	Ca	P
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*Percent*	*p.p.m*
Nuts—Cont.														
Peanut,* *Arachis hypogaea* L.														
Roasted and skinned	606	—	31.81	51.04	11.20	3.66	2.28	0.01	Trace	7	16			4,140
Brazil Nut, *Bertholletia excelsa* Humb. & Bonp.														
....	605	—	17.36	69.94	5.10	3.87	3.72	0.01	46	22	12			7,520
Average		—	19.01	64.85	10.08	3.62	2.43	0.01	25	13	23			4,470
Processed Human Foods														
Corn, *Zea Mays* L. var.														
Cornmeal, granulated	837	—	8.78	0.85	89.54	0.49	0.32	0.02	23	1	None		0.006	590
Corn flakes	836	—	7.89	0.24	88.45	0.35	3.07	0.00	22	2	None		0.006	410
Rice, *Oryza sativa* L.														
Polished	455	—	7.98	0.41	91.16	0.11	0.32	0.02	69	14	32	21		930
Oats, *Avena sativa* L.														
Rolled	456	—	19.01	6.64	71.33	1.03	1.90	0.09	69	12	82	33	0.052	4,670
Wheat, *Triticum aestivum* L.														
Patent Flour, spring wheat	702	—	12.44	1.05	85.89	0.13	0.47	0.02	2	1	None		0.022	1,460
winter wheat	705	—	15.42	1.09	82.93	0.14	0.41	0.01	7	7	Sl. Tr.		0.029	890
Flour, hard wheat	738	—	15.78	1.27	82.35	0.07	0.52	0.01	16	1	Sl. Tr.			1,160
soft wheat	739	—	11.16	1.31	86.89	0.15	0.48	0.01	22	1	Trace			1,140
Average	...	—	13.70	1.18	84.52	0.12	0.47	0.01	12	3	—			1,260
2d clear flour, spring wheat	703	—	22.07	3.97	71.08	0.84	2.03	0.01	53	7	39			4,990
winter wheat	706	—	19.02	2.99	75.62	0.81	1.55	0.01	30	6	46			3,570
Graham flour	742	—	15.44	2.41	78.02	2.19	1.93	0.01	42	22	43		0.052	4,540
Shredded Wheat	840	—	11.30	1.42	83.24	2.32	1.72	0.00	41	5	20		0.047	4,050
Barley, *Hordeum vulgare* L.														
Pearl	454	—	9 65	1.26	86.85	0.87	1.33	0.04	48	6	30	27		2,800

Buckwheat, *Fagopyrum esculentum* Moench.													
Flour	609	—	10.93	2.51	84.44	0.52	1.49	0.11	73	6	16	0.026	3,050
Tapioca, *Manihot esculenta* Crantz.													
Pearl	668	—	0.07	0.05	99.52	0.21	0.15	0.00	23	None	Trace		Trace
Dr. Jackson's Meal	841	—	16.15	2.36	75.45	3.35	2.68	0.01	72	7	42	0.056	6,020
Cattle Feeds Low Protein													
Corn, *Zea Mays* L.													
Cornmeal, Argentine	512	—	11.71	7.23	76.58	2.30	2.18	—	66	6	14		4,760
Hominy meal, yellow	23	—	12.60	7.02	72.06	5.20	2.95	0.17	116	8	20	0.058	6,010
white	22	—	11.90	5.37	76.55	3.73	2.36	0.09	116	6	13		5,230
Wheat, *Triticum aestivum* L.													
Flour middlings	676	—	22.54	2.63	73.39	0.20	1.23	0.01	24	5	8	0.034	2,750
Gray middlings	740	—	18.62	4.49	66.64	6.10	3.97	0.18	173	13	119	0.104	8,950
Bran	21	—	19.28	4.54	61.94	8.16	5.89	0.19	207	30	90		12,240
	741	—	16.26	3.18	63.22	10.39	6.92	0.03	139	22	167	0.112	16,210
Beet, *Beta vulgaris* L.													
Dried Pulp	28	—	10.74	0.20	70.22	15.47	2.91	0.46	298	19	49	0.630	840
	652	—	10.52	0.51	62.45	22.32	3.77	0.43	369	12	13		960
Citrus maxima (Burm.) Merr. var. *uvacarpa* Merr. & Lee													
Dried pulp, granular	813	—	6.64	2.38	70.24	11.70	9.04	0.00	303	2	3	2.603	1,260
shredded	814	—	7.79	10.76	55.82	17.62	7.88	0.13	265	5	Trace		1,470
shredded, with molasses	815	—	9.49	4.49	64.48	11.07	10.42	0.05	267	10	4		1,420
Average	...	—	7.97	5.88	63.52	13.46	9.11	0.06	278	6	2		1,380
Cattle Feeds Medium to High Protein													
Corn, *Zea Mays* L.													
Gluten Feed	515	—	32.41	2.34	50.22	7.46	7.57	—	684	70	36	0.853	6,680
	618	—	34.60	1.59	49.32	6.65	7.47	0.37	955	67	26		10,200
	619	—	30.81	1.77	52.72	7.22	6.65	0.83	649	73	20		10,000
Average	...	—	32.61	1.90	50.75	7.11	7.23	0.40	763	70	27		8,960
Gluten Meal	510	—	47.24	3.64	45.37	2.54	1.21	—	961	49	Trace	0.016	2,200
Corn Distiller's Grains	696	—	33.47	11.44	41.20	12.27	1.14	0.48	137	22	Trace	0.055	3,300

*Not a true nut.

Food Product	Sample No.	Original Moisture	Crude Protein	Crude Fat	Nitrogen Free Extract	Crude Fiber	Crude Ash Soluble	Crude Ash Insoluble	Fe	Cu	Mn	Zn	Ca	P
		Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*p.p.m.*	*Percent*	*p.p.m*
Cattle Feeds, Medium to High Protein—Cont.														
Babassu Meal, *Attalea funifera* Mart.	626	—	27.06	6.36	48.27	12.44	5.05	0.82	378	45	335			10,070
Palm Kernel Meal, *Elaeis guineensis* Jacq.	627	—	20.88	7.89	56.38	10.68	3.87	0.30	179	33	292			7,470
Soybean, *Glycine Soja* (L.) Sieb. & Zucc.														
Meal	511	—	45.95	5.80	36.87	5.58	5.80	—	275	35	29		0.281	6,680
Meal	514	—	46.78	8.09	33.26	5.77	6.10	—	113	19	31			6,790
O. P. Linseed Meal, *Linum usitatissimum* L.	20	—	41.67	6.72	36.80	7.02	5.43	2.36	1,087	31	35		0.355	6,920
Cottonseed Meal, *Gossypium hirsutum* L.	18	—	45.12	7.06	31.46	8.79	7.49	0.08	156	27	16		0.261	11,260
Cottonseed Meal, Egyptian, *Gossypium barbadense* L.	257	—	48.01	8.48	27.74	8.48	6.92	0.37	278	29	19			10,310
Manamar,† Dried fish and kelp	19	5.50	45.33	3.52	17.34	2.22	31.34	0.25	715	25	12			12,300
Blood Flour,† Spray dried	731	7.82	15.16‡	0.17	—	—	4.41	0.00	3,310	9	None			1,000
Blood Meal†	732	12.16	15.59‡	0.17	—	0.75	3.40	0.28	4,524	11	Sl. Tr.			1,740
Roughage														
Corn, *Zea Mays* L.														
Silage	30	73.50	8.09	2.90	59.29	24.27	3.94	1.51	614	18	54		0.257	2,130
Sweet Vernal Grass, *Anthoxanthum odoratum* L.														
Early cut	821	—	18.42	4.33	51.45	16.38	6.51	2.91	608	12	76			4,460
Rhode Island Bent, *Agrostis canina* L.														
Early cut	822	—	19.26	2.96	46.98	20.65	5.69	4.46	454	20	177			4,890
Red Top, *Agrostis tenuis* Sibth.														
Early cut	823	—	18.27	3.35	45.55	20.78	6.20	5.85	706	26	112			4,450
Herd's Grass, Timothy, *Phleum pratense* L.														
Early cut	824	—	18.18	3.33	47.83	20.67	5.72	4.27	786	20	75			4,310
Sheep's Fescue, *Festuca ovina* L.														
Early cut	825	—	16.41	2.89	46.71	26.06	4.38	3.55	426	29	82			3,790

Kentucky Bluegrass, June Grass, *Poa pratensis* L.													
Early cut	826	—	17.34	3.07	46.33	23.36	5.13	4.77	829	31	70		5,030
Orchard Grass, *Dactylis glomerata* L.													
Early cut	827	—	19.69	3.83	41.55	22.43	7.72	4.78	769	33	104		6,900
Hay, Mixed Grasses	27	—	11.00	1.79	48.89	31.55	6.34	0.43	229	19	47	0.580	2,030
Alfalfa Hay, *Medicago sativa* L.													
Long, from California	810	—	15.85	1.56	41.38	33.66	7.20	0.35	493	28	23		2,540
Long, from New York	811	—	17.31	1.89	44.85	29.80	5.81	0.34	210	24	24		2,770
Cut, from Ohio	812	—	16.94	2.33	45.09	27.49	7.88	0.27	235	35	14	1.793	1,350
Average	...	—	16.70	1.93	43.77	30.32	6.96	0.32	313	29	20		2,220
Clover Hay, *Trifolium repens* L.													
White Dutch (var. ?)	828	—	29.43	2.39	43.59	12.78	7.71	4.10	1,537	12	76		5,150
Ladino (var. ?)	829	—	29.58	2.29	44.59	13.34	9.11	1.09	608	9	76	1.664	4,110
Kitchen Waste, Fruit and Vegetables													
Apple, *Pyrus Malus* L.													
Skins, Baldwin	238	80.70	2.42	4.81	82.50	8.35	1.90	0.02	39	5	14		770
McIntosh	236	81.80	1.65	4.81	85.79	6.70	1.03	0.02	30	11	Trace		640
Grapefruit (Florida), *Citrus maxima* (Burm.) Merr. var. *uvacarpa* Merr. & Lee.													
Peel	631	—	5.07	1.98	78.75	9.79	4.41	0.00	21	7	Trace		810
Orange (California), *Citrus sinensis* (L.) Osbeck.													
Peel	629	—	7.69	1.79	77.75	9.39	3.38	0.00	30	5	Trace		900
Grape (Concord) *Vitis Labrusca* L.													
Skins	255	83.60	5.71	3.66	76.76	7.36	6.48	0.03	46	30	Trace		970
Muskmelon, *Cucumis Melo* L.													
Rind	369	—	16.18	1.35	55.19	15.89	11.07	0.32	212	12	20		3,760
Beet (Boston Crosby or Early Wonder), *Beta vulgaris* L.													
Tops, mature, gritty, Fe applied	357	—	13.79	3.66	49.04	11.35	21.36	0.80	713	23	342		3,710
Cu applied	358	—	14.91	3.49	48.93	11.96	20.04	0.67	517	50	271		3,790
Mn applied	359	—	14.02	3.75	47.91	11.05	22.02	1.25	895	30	425		4,890
1 applied	360	—	14.91	3.51	48.08	12.10	19.79	1.61	891	27	358		2,650
Check	361	—	14.49	3.57	48.70	11.88	20.13	1.23	741	28	336		2,690
Average	...	—	14.42	3.60	48.53	11.67	20.67	1.11	751	32	346		3,550

†Excluded from the summary. ‡As nitrogen.

Food Product	Sample No.	Original Moisture	Crude Protein	Crude Fat	Nitrogen Free Extract	Crude Fiber	Crude Ash Soluble	Crude Ash Insoluble	Fe	Cu	Mn	Zn	Ca	P
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	p.p.m.	p.p.m.	p.p.m.	p.p.m.	Percent	p.p.m
Kitchen Waste Fruit and Vegetables—Cont.														
Beets—Cont.														
Tops, mature, very gritty,														
Fe applied	488	—	15.38	3.16	48.57	10.50	20.62	1.77	1,260	15	482			5,690
Cu applied	489	—	15.90	3.13	48.40	10.33	20.53	1.71	1,096	42	425			6,750
Mn applied	490	—	15.83	3.26	48.20	10.26	20.64	1.81	1,256	14	488			7,370
I applied	491	—	16.16	3.31	47.42	10.36	20.89	1.86	1,497	13	653			4,290
Check	492	—	17.13	3.33	46.92	10.24	20.47	1.91	1,341	17	508			4,380
Average	...	—	16.08	3.24	47.90	10.34	20.63	1.81	1,290	20	511			5,700
Turnip, *Brassica Rapa* L.														
Tops, composite of 7	197	86.90	10.32	2.03	59.84	13.34	12.06	2.41	975	8	117			3,290
Skins, composite of 2	193	88.50	8.34	1.27	68.71	11.45	9.80	0.43	324	9	27			4,550
Carrot, *Daucus Carota* L.														
Tops	68	91.20	13.66	1.69	52.12	13.72	17.59	1.22	687	6	6			3,580
Chantenay or Model, tops, very gritty,														
Fe applied	499	—	13.70	2.32	49.75	15.65	15.67	2.91	1,876	9	165			1,590
Fe and S applied	500	—	13.27	2.16	50.67	14.38	14.74	4.78	2,918	10	533			1,630
Cu applied	501	—	13.70	2.28	50.21	14.64	14.97	4.20	2,701	27	195			1,640
Mn applied	502	—	12.80	2.25	49.66	15.00	14.72	5.57	3,384	13	246			1,740
I applied	503	—	13.56	2.25	47.88	14.75	15.25	6.31	3,852	18	247			1,550
Check	504	—	14.28	2.27	46.81	15.01	14.80	6.83	4,096	17	214			1,550
Average	...	—	13.55	2.26	49.16	14.91	15.02	5.10	3,138	16	267			1,620
Sweet Potato, *Ipomoea Batatas* (L.) Poir.														
Skins	250	69.20	2.71	0.82	87.38	4.42	4.60	0.07	66	10	42			1,210
Potato, *Solanum tuberosum* L.														
Skins, Green Mountain	248	80.30	14.00	0.19	75.76	4.03	5.78	0.24	204	24	21			2,240
Irish Cobbler	246	80.20	9.97	0.15	78.75	4.23	6.74	0.16	174	15	21			2,630

Miscellaneous												
White Pine, *Pinus Strobus* L.												
Ground wood	604	—	0.67	2.13	27.71	68.90	0.36	0.23	181	6	21	Trace
Sweet Fern, *Myrica asplenifolia* L.	620	—	12.50	9.32	67.61	7.62	2.30	0.65	352	14	455	710
Buckwheat, *Fagopyrum esculentum* Moench	654	—	14.07	2.95	70.70	10.08	2.14	0.06	69	9	36	3,900
Celery, *Apium graveolens* L.												
Immature	802	—	10.35	1.56	58.22	12.25	17.56	0.06	45	16	22	3,950
Tomato, *Lycopersicon esculentum* Mill.												
Vines, greenhouse raised, Fe applied	683	—	15.32	2.31	36.10	23.26	22.51	0.50	234	25	111	7,900
Cu applied	684	—	16.07	2.61	36.48	21.61	22.56	0.67	302	25	118	6,580
Mn applied	685	—	15.36	2.53	35.80	23.02	22.70	0.59	339	25	70	6,320
I applied	686	—	14.29	2.36	36.17	24.76	22.05	0.37	177	25	20	8,700
Check	687	—	15.03	2.47	36.18	23.81	22.11	0.40	213	29	48	8,930
Average	...	—	15.21	2.46	36.14	23.29	22.39	0.51	253	26	73	7,690
Milk, as received	632	87.19	—	3.85	—	—	0.72	0.00	1.2	0.6	Trace	920
	432	—	—	—	—	—	—	—	1.4	0.1	Sl. Tr.	950
	636	—	—	—	—	—	—	—	1.3	0.2	—	830
	637	—	—	—	—	—	—	—	1.3	0.3	—	790
	638	—	—	—	—	—	—	—	1.5	0.2	—	790
	639	—	—	—	—	—	—	—	1.3	0.2	—	800
Average	...	—	—	—	—	—	—	—	1.3	0.3	—	850
Milk, modified, as received	640	—	—	—	—	—	—	—	2.2	0.7	—	820
Codfish	431	3.94	14.65*	0.74		—	9.48	0.01	41	3	Trace	10,160

*As nitrogen

COLORIMETRIC METHODS EMPLOYED

As has been stated, colorimetric methods were employed for the determination of the mineral elements, based on visual readings with a color comparator with filters, such as a Duboscq. These instruments are subject to personal error and are less satisfactory than a spectrophotometer but were the only apparatus available.

The fundamental theory underlying the use of "Colorimeters" to obtain maximum sensitivity is acknowledged by most analysts but is not properly observed in practice. It requires a preknowledge of the transmission curve of the solute under examination and the selection of a filter (complementary) having its highest transmission in the spectral region where the solute exhibits maximum absorption. Such narrow band color filters, however, are relatively dense and their use is precluded in some instances by their inability to transmit sufficient rays (monochromatic) for accurate measurement from the light provided. This necessitates a filter of wider band and of less selectivity with probably some sacrifice in accuracy.

The color filters recommended in the text are based on actual determinations made by P. A. Clifford and A. K. Klein of the Food and Drug Administration on the different colored solutions employed for trace metals. The Corning Glass Works supplies the various units necessary for the combined filters.

The so-called C. P. chemicals used in the analyses have occasionally proved a source of trouble. For instance, iron has been found in the mineral acids in appreciable amounts and copper in the citric acid. Some lots of potassium thiocyanate failed to produce a stable color with iron, and potassium periodate to oxidize manganese salts to manganic acid. One lot of ammonium molybdate was largely insoluble, and amino-naphthol-sulfonic acid gave rise to a precipitate in the phosphate solution, etc. In some cases purification was possible, but in others replacement was the only solution.

The methods are based on well-known reactions and have proved entirely satisfactory in the hands of many workers in this laboratory over a long period of time. Many new processes have appeared in the literature within recent years, but there appears to be no particular advantage in their adoption.

Preparation of Ash Solutions

Wet Combustion

Reagents

Sulfuric acid, sp. gr. 1.84, 95%.

Nitric acid, sp. gr. 1.42, 70%.

Water redistilled from glass.

The acids should be free from all elements under determination, as results corrected for impurities are less dependable. Perchloric acid, ammonium persulfate, and other oxidizing agents are occasionally employed but are seldom necessary.

Method

Transfer 10 grams of finely ground (1 mm.) air-dry material to a 500 ml. Kjeldahl flask, add 8 to 10 glass beads (6 mm.) and concentrated nitric acid, drop by drop, from a separatory funnel until frothing ceases and the organic matter is largely disintegrated. Add 20 to 25 ml. of concentrated sulfuric acid, heat over a low flame, and continue the addition of nitric acid until the solution becomes colorless.

Cool, add 25 ml. of water, and boil until the nitric acid has been expelled. Cool, add 200 ml. of water, shake occasionally, and allow to stand over night.

Transfer to a 500 ml. volumetric flask, make to volume at 25° C, filter, and determine the ash constituents in various aliquots. Such solutions will stand a year without discoloration.

With milk, fruit juices, and other liquid products, 100 grams are generally employed.

Determination of Iron

Reagents

Standard iron solution.—Dry reagent iron wire free from surface oxidation[1] and dust, transfer 2 grams (about 21.4 feet) to a volumetric flask, add about 200 ml. of water, 50 ml. of sulfuric acid (1-1), and 5 ml. of concentrated nitric acid. Boil until solution is complete and the nitrous oxide expelled, cool, and make to 2000 ml. at 25° C. One ml. contains 0.0010 gram of iron.

Dilute iron solution.—To 20 ml. of the standard iron solution add 200 ml. of sulfuric acid (1-1) and sufficient water at 25° C to make 2000 ml. One ml. contains 0.00001 gram of iron.

Potassium thiocyanate solution, KCNS. 400 grams per 2000 ml. (Occasional lots will not produce a stable color.)

Nitric acid, 5%.—Boil 100 ml. of colorless concentrated nitric acid in 500 ml. of water, cool, and make to 2000 ml.

Method

Transfer an aliquot (25 ml.) of the original ash solution containing about 0.0001 gram (0.02-0.60 mg.) of iron to a 50 ml. volumetric flask, add 5 ml. of dilute nitric acid, mix, and allow to stand over night. Add 10 ml. of potassium thiocyanate, make to volume, and mix thoroughly. Compare the color, $Fe(CNS)_3$, in a Duboscq, using a blue color filter (spectral centroid about 465 millimicrons), against 10 ml. of dilute iron solution treated in exactly the same manner.

$$\% = \frac{sR}{R_1} \times 200 \text{ for } 0.50 \text{ gram (F)}$$

$$= \frac{0.02R}{R_1}$$

$$\text{p.p.m.} = \frac{200R}{R_1}$$

s = grams of standard employed.
R = scale reading at which the standard was set.
R_1 = scale reading of the unknown.
F = factor for converting the aliquot to percentage or p.p.m.

The limit of error between parallel solutions should not exceed 0.00020% or 2 p.p.m.

Determination of Copper

Reagents

Standard copper solution.—Dry reagent electrolytic copper foil (0.002″) free from surface oxidation[1] and dust, transfer 2 grams (about 6 square inches) to a volumetric flask, add 200 ml. of water, 50 ml. of sulfuric acid (1-1), and 10 ml. of concentrated nitric acid. Boil until solution is complete and the nitrous oxide

[1]Cleaned with fine crocus cloth.

expelled, cool, and make to 2000 ml. at 25° C. One ml. contains 0.001 gram of copper.

Dilute copper solution.—To 20 ml. of the standard copper solution add 1000 ml. of sulfuric acid (1-1) and sufficient water at 25° C. to make 2000 ml. One ml. contains 0.00001 gram of copper.

Sodium diethyl dithiocarbamate solution. 2.5 grams per 1000 ml.

$$S=C\begin{matrix}\nearrow S-Na \\ \searrow N=(C_2H_5)_2\end{matrix}$$

Ammonium citrate solution, 0.5*M*. $(NH_4)_2HC_6H_5O_7$.
Dissolve 226.2 grams of diammonium citrate or 210.1 grams of citric acid in water, add ammonium hydroxide until alkaline to litmus, and make to 2000 ml. Transfer 250 ml. to a 1000 ml. glass-stoppered pear-shaped separatory funnel, add an excess of diphenylthiocarbazone (dithizone) solution (usually 3, 2, and 1 ml. respectively), and shake out with three 25 ml. portions of carbon tetrachloride to a green color. Discard the solvent layers and filter the aqueous portions through washed ashless paper.

Ammonium hydroxide, concentrated.
Nitric acid, concentrated.
Carbon tetrachloride, reagent or redistilled.

Method

Evaporate an aliquot (100 ml.) of the original ash solution containing about 0.00005 gram (0.01–0.30 mg.) of copper, together with 10 ml. of concentrated nitric acid, in a 150 ml. Griffin beaker on a steam bath. Wash down the sides of the beaker with 10 ml. of water, add concentrated ammonium hydroxide until alkaline to litmus, and cool. Transfer the solution to a 500 ml. glass-stoppered separatory funnel (pear-shaped with a short delivery tube), and wash to a volume of about 85 ml. Add a few drops of ammonium hydroxide in excess, 10 ml. of ammonium citrate, 5 ml. of carbamate solution, and mix. Add 10 ml. of carbon tetrachloride (measured carefully), stopper the separatory funnel, shake for about 2 minutes, and allow to layer. Wipe the delivery tube with filter paper, rinse with a few drops of the carbon tetrachloride solution containing the colored copper salt (brownish-yellow), then draw off the remainder through a small coarse filter (to remove traces of moisture) into a weighing bottle, and stopper to prevent evaporation.

Precautions.—If iron is precipitated on the addition of ammonium hydroxide, which frequently occurs with soils, dried blood, etc., centrifuge the precipitate and decant the clear solution into the separatory funnel. Wash the precipitate twice with water containing a few drops of ammonia, centrifuge and decant, then proceed as usual. The carbon tetrachloride seldom forms an emulsion on shaking out the test, but this has been observed several times on the determination of blanks.

Compare the color in a Dubosq, using micro cups and a blue color filter (spectral centroid about 435 millimicrons), against 5 ml. of dilute copper solution treated in exactly the same manner. In hot weather the rapid evaporation of the carbon tetrachloride in the cups necessitates a frequent change of standard.

$$\% = \frac{sR}{R_1} \times 50 \text{ for 2 grams (F)}$$

$$= \frac{0.0025R}{R_1}$$

$$\text{p.p.m.} = \frac{25R}{R_1}$$

s = grams of the standard employed.
R = scale reading at which the standard was set.
R_1 = scale reading of the unknown.
F = factor for converting the aliquot to percentage or p.p.m.

The limit of error between parallel solutions should not exceed 0.00010% or 1 p.p.m.

Determination of Manganese

Reagents

Standard sodium oxalate solution.—Dry sodium oxalate (Soerensen's), transfer 0.3050 gram to a volumetric flask, dissolve in water, and make to 1000 ml. at 25° C. Unstable, use a fresh solution.

Potassium permanganate solution.—Dry reagent potassium permanganate 0.2877 gram[1] per 2000 ml. at 25° C. One ml. contains 0.00005 gram of manganese.

Potassium periodate, KIO_4 (G. Frederick Smith Chem. Co.).

Nitric acid, concentrated.

Sulfuric acid, 2 N, 9.26%. 110 ml. per 2000 ml.

Sulfuric acid, 1-1.

Standardization of Manganese Solution

$$5Na_2C_2O_4 + 2KMnO_4 + 8H_2SO_4 = 2MnSO_4 + 5Na_2SO_4 + K_2SO_4 + 10CO_2 + 8H_2O$$

5 x 134.014 : 2 x 158.026 :: 0.30497 : 0.14385 potassium permanganate

5 x 134.014 : 2 x 54.93 :: 0.30497 : 0.05 manganese in 1000 ml.

Titrate the potassium permanganate against 10 ml. of standard sodium oxalate solution to which has been added 5 ml. of 2 N sulfuric acid in a 150 ml. Erlenmeyer flask at 80° C to a faint pink that will persist for about 1 minute.

$KMnO_4$ titer : 10 :: 0.05 : X actual manganese in 1000 ml.

Method

Evaporate an aliquot (100 ml.) of the original ash solution containing about 0.00025 gram (0.04-1.5 mg.) of manganese, together with 10 ml. of concentrated nitric acid, in a 150 ml. Griffin beaker on a steam bath. Wash down the sides of the beaker with 10 ml. of water, cover with a watch glass, and heat on a steam bath. Add from 0.2 to 0.5 gram of potassium periodate and continue the heating until the pink color develops (2 hours).[2]

$$2MnSO_4 + 5KIO_4 + 3H_2O = 2HMnO_4 + 5KIO_3 + 2H_2SO_4.$$

Cool, filter through a sugar tube with a glass wool and asbestos felt into a 50 ml. volumetric flask (glass-stoppered) containing a small amount of periodate, and wash nearly to volume. Stopper the flask and again heat on the steam bath to develop the maximum color (2 hours). Cool, make to volume, and mix.

Compare the color in a Dubosq, using a green color filter (spectral centroid about 515 millimicrons) when the amount of manganese is appreciable, against

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[1]Preferably 0.30 gram to allow for impurities and slight decomposition. Filter through porous glass or asbestos to remove insoluble matter.

[2]The presence of hydrochloric acid vitiates the results.

5 ml. of potassium permanganate solution treated in exactly the same manner after the addition of 5 ml. of sulfuric acid (1-1). For traces of manganese, discard the color filter and use the white porcelain surface and a more dilute standard.

$$\% = \frac{sR}{R_1} \times 50 \text{ for 2 grams (F)}$$

$$= \frac{0.0125R}{R_1}$$

$$\text{p.p.m.} = \frac{125R}{R_1}$$

s = grams of the standard employed.
R = scale reading at which the standard was set.
R_1 = scale reading of the unknown.
F = factor for converting the aliquot to percentage or p.p.m.

The limit of error between parallel solutions should not exceed 0.00010% or 1 p.p.m.

Determination of Phosphorus
(Modified Fiske and Subbarow)

Reagents

Standard phosphate solution.—Dry monopotassium phosphate (Soerensen's), transfer 0.8786 gram to a volumetric flask, add water, 25 ml. of 10 N sulfuric acid, and make to 2000 ml. at 25° C. One ml. contains 0.00010 gram of phosphorus.

Ammonium molybdate solution, 2.50%.—Dissolve 50 grams of ammonium molybdate $(NH_4)_6Mo_7O_{24}.4H_2O$ in 400 ml. of water and pour slowly with agitation into 1000 ml. of 10 N sulfuric acid and make to 2000 ml.

1 *Amino-2 naphthol-4 sulfonic acid solution,* 0.10%.—Dissolve 1 gram[1] of the purified compound in a mixture of 975 ml. of 15% anhydrous sodium bisulfite and 25 ml. of 20% anhydrous sodium sulfite, and filter into an amber bottle. In some instances an additional 1 or 2 ml. of sodium sulfite may be necessary to insure complete solution. The solution is unstable but is serviceable for several weeks if protected from heat and light.

Sodium bisulfite, anhydrous, 15%	150 grams per 1000 ml.
Unstable, use a fresh solution.	
Sodium sulfite, anhydrous, 20%.	20 grams per 100 ml.
Sulfuric acid, 10 *N*, 38.21%.	564 ml. per 2000 ml.

Purification of 1 *amino-2 naphthol-4 sulfonic acid*

Prepare a solution of 150 grams of anhydrous sodium bisulfite and 5 grams of anhydrous sodium sulfite in 1000 ml. of water and heat to 90° C. Add 15 grams of amino-naphthol-sulfonic acid, shake until dissolved, and filter with suction to remove impurities. Cool the filtrate, add 10 ml. of concentrated hydrochloric acid, and allow to stand over night in a refrigerator to precipitate. Filter through a Buchner funnel, wash thrice with cold water and twice with cold alcohol, dry in a vacuum oven at room temperature, and preserve in an amber glass-stoppered bottle.

Method

Transfer an aliquot (10 ml.) of the original ash solution containing about 0.0005 gram (0.08-3.00 mg.) of phosphorus into a 100 ml. volumetric flask, dilute

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[1]The recent product proved more reactive than formerly; hence less is employed.

to about 70 ml., add 10 ml. of ammonium molybdate solution, mix, add 5 ml. of amino-naphthol-sulfonic acid solution, make to volume, mix thoroughly, and allow to stand about 10 minutes to develop its maximum color (molybdenum blue, Mo_3O_8). Cold or strongly acid solutions react slowly.

Compare the color in a Dubosq, using an orange color filter (spectral centroid about 645 millimicrons), against 5 ml. of standard phosphate solution treated in exactly the same manner.

$$\% = \frac{sR}{R_1} \times 500 \text{ for } 0.20 \text{ gram (F)}$$

$$= \frac{0.25R}{R_1}$$

$$\text{p.p.m.} = \frac{2500R}{R_1}$$

s=grams of the standard employed.
R=scale reading at which the standard was set.
R_1=scale reading of the unknown.
F=factor for converting the aliquot to percentage or p.p.m.

The limit of error between parallel solutions should not exceed 0.005% or 50 p.p.m.

Synopsis of Reaction

$8(NH_4)_6Mo_7O_{24}.4H_2O+2H_3PO_4+21H_2SO_4=2(NH_4)_3PO_4.12MoO_3+$
$32H_2MoO_4+21(NH_4)_2SO_4+24H_2O$
$3(12MoO_3)+4NH_2=12Mo_3O_8+4NO_2+4H_2O$

Determination of Zinc

Reagents

Standard zinc solution.—Dry reagent zinc foil (0.002") free from surface oxidation[1] and dust, transfer 2 grams (about 8.43 square inches) to a volumetric flask, add about 200 ml. of water and an excess of distilled hydrochloric acid. Boil until solution is complete, cool, and make to 2000 ml. at 25° C. One ml. contains 0.0010 grams of zinc.

Dilute zinc solution.—To 4 ml. of the standard zinc solution add sufficient water at 25° C to make 2000 ml. One ml. contains 0.000002 gram of zinc.

Hydrochloric acid, 0.20 *N.*—Distill the hydrochloric acid into cold "metal free" water by allowing concentrated sulfuric acid to drip from a separatory funnel into concentrated hydrochloric acid below the surface, and dilute to the required strength at 25° C.

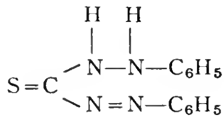
Ammonium hydroxide, 0.20 *N.*—Distill the ammonium hydroxide to about 70° C into cold "metal free" water and dilute to the required strength at 25° C.

Sodium diethyl dithiocarbamate (carbamate) solution.—2.5 grams per 1000 ml. Preserve in a brown bottle.

Diphenylthiocarbazone (*dithizone*) *solution.*—Dissolve 0.03 gram of dithizone in 20 ml. of 0.20 N ammonium hydroxide, crushing the aggregates to facilitate solution, and transfer to a 500 ml. pear-shaped separatory funnel with 180 ml. of water. Shake out with 25 ml. portions of carbon tetrachloride to a green color and discard the solvent layers. Add 45 ml. of 0.20 N hydrochloric acid, 5 ml. of water, and shake out with 50 ml. portions of carbon tetrachloride, filter the solvent

[1]Cleaned with fine crocus cloth.

layers through dry ashless paper and dilute to 200 ml. with carbon tetrachloride. Reasonably stable in a brown bottle.



Ammonium citrate solution, 0.5M. $(NH_4)_2HC_6H_5O_7$. Dissolve 226.2 grams of diammonium citrate or 210.1 grams of citric acid in water, add ammonium hydroxide until alkaline to litmus, and make to 2000 ml. Transfer 250 ml. to a 1000 ml. glass-stoppered pear-shaped separatory funnel, add an excess of dithizone solution (usually 3, 2, and 1 ml. respectively), and shake out with three 25 ml. portions of carbon tetrachloride to a green color. Discard the solvent layers and filter the aqueous portions through washed ashless paper.

Carbon tetrachloride, reagent or redistilled.

Potassium cyanide solution, 10%. 50 grams per 500 ml.

Method—Dry Combustion

Transfer 2 or 4 grams of finely ground (1 mm.) air-dry material to a flat-bottomed platinum ash dish, incinerate carefully in an electric muffle (with the door open), continue the heating (door closed) at 500° C (visible redness) until a white or gray ash is obtained. If carbon persists, moisten the ash with water to bring the particles to the surface, evaporate to dryness on a steam bath and reheat. Transfer the ash with small portions of hot water, distilled hydrochloric acid, and a rubber policeman to a 150 ml. Griffin beaker, add an excess of distilled hydrochloric acid, and evaporate to dryness on a steam bath. Take up with 20 ml. of 0.20 N hydrochloric acid, heat to boiling, and transfer to a 100 ml. volumetric flask, cool make to volume at 25° C. and pass through a dry filter.

Transfer 10 ml. of the ash solution containing about 0.00001 gram (0.002 to 0.025 mg.) of zinc to a 500 ml. glass-stoppered separatory funnel (pear-shaped with a short delivery tube). Add 23 ml. of water, 7 ml. of 0.20 N ammonium hydroxide, 10 ml. of ammonium citrate solution, 15 ml. of carbon tetrachloride, and dithizone solution in small portions until a yellow color is imparted to the ammoniacal aqueous solution after shaking. Shake for at least 2 minutes to extract copper, lead, and zinc (also cobalt, cadmium, and mercury (ic) when present). Allow the mixture to separate and draw off the solvent layer into a second separatory funnel. Discard the ammoniacal aqueous layer, which should be yellow and contain the non-reacting bases and acids.

To the carbon tetrachloride layer, add 45 ml. of water and 5 ml. of 0.20 N hydrochloric acid and shake out to extract the lead and zinc as chlorides in the acid aqueous solution, which should be colorless, leaving the copper in the solvent layer which may be used for the determination of copper if desired although a larger aliquot of the original ash solution is preferable.

To the acid aqueous solution add 20 ml. of water, 15 ml. of 0.20 N ammonium hydroxide, 10 ml. of ammonium citrate solution, 5 ml. of carbamate solution, 10 ml. of carbon tetrachloride, a measured quantity of dithizone solution (in small portions) sufficient to impart a yellowish tint to the ammoniacal aqueous solution after shaking, then additional carbon tetrachloride to a total volume of 15 ml. including that from the dithizone. A greater dilution may be necessary for some samples when a spectrophotometer is employed. This procedure is

the so-called single color method. An excess dithizone produces a mixed color and is preferred by some analysts.

Shake out for at least 2 minutes to extract the colored zinc salt, allow to separate, rinse the delivery tube with a few drops of the solvent layer, and draw off the remainder through a dry ashless filter (to remove traces of moisture) into a weighing bottle and stopper to prevent evaporation.

Compare the color in a comparator or spectrophotometer using a narrow band green color filter (spectral centroid 515 millimicrons) against 5 ml. of dilute zinc solution treated in exactly the same manner.

$$\% = \frac{sR}{R_1} \text{ x } 250 \text{ for } 0.40 \text{ gram (F)}$$

$$= \frac{0.0025R}{R_1}$$

$$\text{p.p.m.} = \frac{25R}{R_1}$$

s=grams of the standard employed.
R=scale reading at which the standard was set.
R_1=scale reading of the unknown.
F=factor for converting the aliquot to percentage or p.p.m.

Since a small amount of zinc will frequently be found in the reagents after careful purification, $\frac{(s+B)R}{R_1}$ should be substituted in the calculations and the blank deducted.

Example— $\frac{R}{R_1} = \frac{B}{s+B}$ $\quad R(s+B) = R_1B;$ $\quad \frac{5}{25} = \frac{B}{10+B}$ $\quad B = 2.50$

The limit of error between parallel solutions should not exceed 0.0003% or 3 p.p.m.

If due care is exercised in the manipulation, no modifications will be found necessary such as a second shaking out with carbon tetrachloride in the three extractions, etc. With proper color filters the mixed color method is easier to handle.

An aliquot of a sulfuric solution prepared by wet combustion may be used for the determination of zinc and has been found to yield similar results.

Lead may be determined in a similar manner by adding 10 ml. of potassium cyanide solution instead of carbamate in the third extraction to inhibit the zinc.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

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Pasture Culture in Massachusetts

By William G. Colby

Pastures are of great economic importance in Massachusetts agriculture, and this study represents an attempt to organize such available information as may have a bearing on their best management.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

PASTURE CULTURE IN MASSACHUSETTS

By William G. Colby,* Research Professor of Agronomy

CONTENTS

INTRODUCTION

Grass, for many years the foundation of the agriculture of Massachusetts, is still one of the State's most important agricultural crops. Interest in grass and grasslands has increased greatly in recent years not only among livestock farmers seeking a satisfactory solution to their feed problem but also among agricultural leaders interested in the conservation of soil resources. Certain leaders have enthusiastically spoken of developing what they have called "a grassland agriculture."

However, in most of these discussions on the value of grass as a feed or as a conserver of soil resources very little attention has been given to the requirements of grass as a crop. Conditions have greatly changed since grass grew "spontaneously" in Massachusetts "even on the driest grounds." At the present time, grass, as a crop, is no different from any other. To grow it successfully certain cultural requirements must be met and certain rules of management must be observed. The aim of this bulletin is to outline in general what these basic requirements are and to advance insofar as is possible the fundamental reasoning underlying these requirements.

During the three hundred years that have elapsed since the Pilgrims imported their first cattle in 1624, many observations, experiences, and experiments have been recorded concerning the pastures of Massachusetts. In an effort to assemble all available pertinent information on grass and grassland management in Massachusetts, historical as well as current sources of information were extensively reviewed.

For the period of the seventeenth and eighteenth centuries, such information must be gleaned from the descriptive writings of early travelers and historians, from various private records in the form of letters, diaries, and account books, and from early colonial reports and town records. Beginning with the nineteenth century, the record is much more complete. Books and treatises on agriculture and agricultural practices were published; several agricultural periodicals were founded; and newly organized agricultural societies in Massachusetts began to publish their reports and proceedings. Since sheep and cattle grazing were

*The writer acknowledges with sincere appreciation helpful criticism and advice from Professor Wm. A. Albrecht, Chairman Department of Soils, University of Missouri; John B. Abbott, Director of Agricultural Research, American Cyanamid Company; and Wilbur J. Locke, County Agricultural Agent, Hampden County, Mass.

important industries at that time, frequent reference is made in these sources to pastures and pasture management.

Toward the middle of the nineteenth century, the Massachusetts State Board of Agriculture was established. This organization coordinated and greatly extended the work of the local agricultural societies. Through its annual reports, it made public the observations and experiences of many successful farmers, the ideas and opinions of leading agriculturists, and the results of early experiments in the agricultural sciences. A large amount of valuable practical information concerning the pastures of this State was accumulated in this way, much of which is extremely helpful to anyone working on problems associated with present-day pastures. It is a singular fact that there are very few standard practices or modern innovations in the field of pasture management for this section of the country that have not been discussed in more or less detail in some of these old reports.

While a body such as the State Board of Agriculture was able to perform the very important task of collecting and publishing much practical information of a general nature, it was unable to sponsor or carry on scientific research to obtain more specific information. This need was met during the latter part of the nineteenth century by the establishment of the agricultural experiment stations which began to conduct detailed scientific investigations in the various sciences associated with agriculture.

As a result of these activities, together with those of other scientific organizations, a scientific basis has been worked out for many of the soil management practices, cultural methods, and harvesting procedures which are followed in the production of most field crops. The pasture crop is an exception. Although some attention has been given to pastures and to the production of pasture herbage, this crop has never been given the consideration that it needs or merits. The present approach is an attempt to formulate the fundamental principles of successful pasture production in Massachusetts by integrating the general information which has accumulated from many past years' observations with specific information obtained from researches in the different plant and soil sciences during recent years.

THE SOILS OF MASSACHUSETTS

" . . . if the fundamental principles of the soil are understood, you . . . will find their applications to practice."

The following discussion on soils, although by no means exhaustive, is nevertheless an endeavor to present in clear perspective some of the outstanding characteristics and essential knowledge of the soils of Massachusetts. It is included here in order to facilitate a better understanding of why our pasture areas have for the main part become so badly "run out" and also to show how some of these lands may now be best treated to restore them to their most efficient level of productivity.

The Soil Profile

The unit now in general use for describing a soil or for comparing one soil with another is known as the "soil profile." A soil profile may be regarded as that portion of a vertical cross-section of earth which includes the complete succession of soil layers or horizons from the surface down to the geological parent material. Profile layers are grouped under three heads: the A-horizon corresponds roughly to the topsoil; the B-horizon to the subsoil; and the C-horizon

to the parent material from which the soil was derived. Perhaps at this point it would be well to distinguish between the formation of soil material chiefly through geological processes of weathering, and the differentiation of this material into layers or horizons through the processes of profile development. According to Professor G. W. Robinson:

> We must regard weathering, physical and chemical, as essentially a geological process, fulfilled, it is true, in the superficial layers of the earth's crust in close relationship with the soil and its processes. The development of the soil profile must be regarded as superimposed on the geological process of rock weathering.[1]

The importance of a careful consideration of the soil profile is shown by the following quotation, also from Robinson:

> The soil profile is the significant factor in the study of relationship of the soil to plants, not only because the profile embraces the root system of plants growing on the soil but also because the all-important factors, moisture and air, can be defined only in terms of the soil profile and not in terms of the laboratory samples. It is important also because a study of its characters can give information as to its probable behavior under different types of management and as to its suitability for different crops. In the soil profile we can read the past history of the soil and forecast its future possibilities.[2]

Although the major characteristics of fully developed soil profiles under virgin conditions are largely determined by climatic forces; in regions like Massachusetts, where the soils are young and their profiles immature, other factors such as the nature of the parent geological material exert strong modifying influences. With soils long farmed, pronounced alterations from virgin conditions have been brought about as a result of tillage, cropping, and fertilizer practices. Therefore, to fully understand the nature of Massachusetts soils and to comprehend their limitations and potentialities, the modifications resulting from human intervention must be carefully considered in conjunction with the effects of climatic and geological factors.

The Influence of Geology

Since geological factors determine the nature of the parent soil material, it seems advisable to indicate briefly the geological background of the present land topography of Massachusetts. Leading up to this present topography is a long history replete with a great variety of geological activity. From the earliest era of the geological time scale, long periods of deposition have alternated with long periods of profound erosion. At times uplifting processes were so violent that lofty mountain systems were raised, accompanied by much tilting and folding and subsequent faulting of rock strata. Volcanic action has also occurred intermittently, whereby great quantities of molten igneous material were forced up into the sedimentary strata and occasionally appeared as lava outpourings on the surface. These mountain systems have been largely worn away so that the present land surface of Massachusetts exemplifies well the descriptive terminology often given the New England area—"a worn-down mountain region." The removal of vast quantities of material through prolonged erosive action has exposed a great variety of rocks of different ages and of different physical and chemical characteristics. The great diversity in the nature of the parent rock material from which our soils have been developed has been one factor, though not the most important, in the formation of the many varied types of soils which are now found in the State.

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[1]Mother Earth—Letters on Soil (London, 1937), p. 63.

[2]Ibid., p. 14.

The last geological event of major significance which strongly affected the character of Massachusetts soils was the spreading of vast ice sheets over the whole of New England during a comparatively recent Ice Age. Great ice masses moving over the State in a southerly direction scoured rock and soil surfaces to carry along great quantities of heterogeneous materials ranging from fine clay through sand and gravel to huge boulders. After the melting of the ice, these materials were left as an irregular veneering over most of the State's surface.

According to W. J. Miller, "Most of the deposits made during the ice advance were obliterated by ice erosion, but those formed during the ice retreat have been left practically intact except for the small amount of post-glacial erosion."[3] As a result, the land surface of most of Massachusetts is that of a typical glaciated country. A mantle of unsorted glacial till covers the more level areas. Well-sorted outwash materials occur along valley walls and on valley floors, while old glacial lake beds yield considerable deposits varying in physical character and depth.

The presence of hundreds of small lakes and the occurrence of many bogs and marshes indicate a condition of imperfect and haphazard drainage, and this is typical of recently glaciated country. Other formations peculiar to glacial action also occur, among the most important being the many low, elongated, distinctively rounded hills called drumlins, which are widely distributed over the State.

This wide variety of glacial formations and remains has given rise to the development of equally variable soils. Because glaciation was relatively recent, these soils are young and the profiles are comparatively immature; hence they are much influenced by the parent rock material from which they have been derived. Thus may be attributed to the glacier the necessity for classifying an unusually large number of soil types which differ in physical characteristics, chemical composition, and drainage conditions.

Influence of Climate

Cool temperatures and moderately high rainfall (40 to 45 inches annually) characterize the climate of Massachusetts. Since such conditions favor the development of forest trees, it is not surprising to learn from historical records that a natural cover of mixed forest trees spread over the whole of Massachusetts. The rich and varied character of the vegetation is indicated by an observer in 1775, who writes as follows: "I should not forget the woods, which, in the parts not brought into culture, are very noble; they consist of oak, ash, elm, chestnut, cypress, cedar, beech, fir, sassafras, and shumac."[4]

The surface of the ground in these virgin forests was covered with a thick layer of organic matter or "vegetable mould," as it was first called, which was composed of leaves of forest trees, forest undergrowth, and other forms of forest debris. This layer is described by an early writer as being "fattened by the continual fall of leaves from trees growing thereon" and as covering the ground "to a spit's depth"[5] (a "spit" was approximately one foot). Still another report states that in Berkshire County "the first settlers feared that they would have no building-material, so deeply were the stones covered by the richness of the forest mould."[6] As long as a forest cover remains, this layer is continually being added to on the surface, and, when not frozen, continually undergoing decomposition beneath the surface. Since cool temperatures do not favor its rapid oxidation, the accumulative process is faster than the wasting-away process. As a result, a

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[3]The Geological History of the Connecticut Valley (Northampton, 1921), p. 63.

[4]American Husbandry [London, 1775] (1939 ed., New York), p. 42.

[5]New England Quarterly, IX (1936), 220.

[6]Mass. State Bd. Agric. 26th Annual Report (1878), Pt. II, p. 29.

peaty humus layer of considerable depth frequently accumulates.

A moderately high rainfall has subjected all soil layers including the humus layer to a strong washing or leaching action, which has the effect of removing material both chemically and physically from the surface soil layers. Some of this material may be redeposited at lower levels in the B-horizon, and some may pass on through the profile and be lost altogether in the drainage waters. Frequently chemical action is particularly strong in the A-horizon. Practically all readily soluble salts are carried away, together with a considerable proportion of the bases, including calcium, magnesium, potassium, and sodium. These bases, according to Robinson, "in the completely leached profiles of humid climate . . . are lost in the drainage; the profile falls in base-status and becomes acid until the loss in bases is just balanced by gains from the weathering of minerals in the soil."[7] The same author goes on to say:

> When the base-status of the soil is lowered by leaching out of bases, the clay complex may undergo decomposition. In the initial stages, this may result simply in the liberation of free silicic acid, alumina, and ferric oxide, such a change being betokened by the yellowish, orange, or brown color of hydrated ferric oxide. Where the removal of bases is more accentuated, ferric oxide, and in extreme cases, alumina, may pass into solution associated with humic acids, and be removed from the upper horizons, which thereby acquire a bleached appearance. Deposition of ferric oxide and alumina occurs at lower levels, giving a yellowish-brown sequioxide B-horizon, which in extreme cases may be hardened to a pan.

The presence of a well-defined bleached A_2-layer and a well-developed pan formation or "orterde" is characteristic of a number of important soil types in Massachusetts. The soil profile which develops under such circumstances is known as a "podzolized" profile and the process itself as "podzolization." It is characteristic of a great group of soils known as podzols or as podzolic soils.

Practically all soil types in Massachusetts are podzolic in nature. It is not difficult to understand, therefore, why the profiles of almost all soil types are quite similar in their chemical characteristics. There are, of course, marked variations between the profile characteristics of different soil types, but these variations are due primarily to the diversity of the parent soil material and to differences in the extent to which the process of podzolization has taken place.

Brown Podzolic Soils

A majority of the soil types belong to a subgroup known as "brown podzolic soils" or "brown forest soils." They have been characterized as imperfectly developed podzols "having, in timbered areas, an organic mat on the surface and a very thin gray leached [or bleached] horizon just below it—usually less than an inch thick. The B-horizon is largely yellowish brown in color and has only the beginnings of a dark-brown orterde just below the gray A-horizon."[8] Some of the agriculturally important soil series belonging to this group are the Gloucester, Plymouth, Charlton, Paxton, Wethersfield, and Cheshire series.

Podzols

In the eastern part of the State where the parent materials contain a high proportion of quartz sand and where the vegetation was largely coniferous, and also in the western highlands where the climate is cooler, groups of soils are found which are more completely podzolized and are classified as true podzols. The A-horizon is more intensely leached, the bleached layer thicker and more clearly defined, and the pan formation or orterde more fully developed. The less agriculturally important soils of the Berkshire, Worthington, Becket, Hermon, Hinckley, and Duke series are all included in this group.

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[7]Mother Earth, p. 66.

[8]Soils and Men, U. S. Dept. Agric. Yearbook (1938), p. 1029.

Ground-Water Podzols

In poorly drained areas where the water table is close to the surface, a modified type of podzolization occurs. Fluctuations in the ground-water level produce a zone where alternate conditions of oxidation and reduction occur. A characteristic mottling and staining, resulting from the precipitation of iron oxides, is found in this zone, and the permanently saturated zone below has a typical gray or bluish-gray color. Soils of the Whitman, Peru, and Sudbury series are all examples of ground-water podzols.

Influence of Cultivation

Before the advent of any human civilization in this region, the natural forest cover served to a considerable extent to counteract the serious effects of leaching. This was particularly true for the various plant food elements in the soil. Before these could be washed out of the profile and lost in the drainage, they were removed by plant roots and utilized for carrying on growth and other normal life processes. After being taken up from the soil in this manner, these elements were returned to the soil surface as dead plant remains, to add to and become a part of that gradually increasing layer of organic matter or humus. Then, when environmental conditions were such as to accelerate the complete decomposition of these plant remains or soil humus, simple plant food elements were again released in the soil and were again taken up by living plants to produce new plant growth. Thus a cycle was established eons ago. Changing little in nature, an ever thicker layer of humus was built up which endured until the coming of civilization.

It is particularly important at this time to point out that, because of the strongly leached character of the mineral fraction of the soil, the non-mineral fraction or soil humus represented the only real reserve or accumulation of soil fertility. As the surface layer of organic matter or "vegetable mould" increased in thickness, just so much did the reserve supply of soil fertility increase. This important relationship was recognized by Henry Colman, when in 1841 he wrote:

> In a forest, the soil is not injured by the Growth of the wood but rather is enriched . . . because the annual decaying matter from these trees, these leaves, and rotten limbs is continually accumulating on the Ground, passing into a state of decomposition and increasing the vegetable mould.[9]

Nature's scheme of fertility conservation proceeded, with constructive forces slightly outweighing destructive forces, until the coming of human civilization, at which time this natural balance was thrown in the other direction. It began in a limited way with the Indians, who, according to an early writer, "at the Spring and the fall of the leafe" were accustomed to "fire the country," burning the underbrush and the younger trees, so that the woods were "thin of Timber in many places, like our Parkes in England."[10] In addition to restricting the growth of shrubs and young trees, the firing of the woods also destroyed large quantities of dry organic material, since, according to another writer in 1632, "it consumes all the underwood and rubbish.[11] According to Dwight, "The grounds, which were covered with Oak, Chestnut, etc. or with Pitch Pine, were selected, for this purpose, because they alone were, in ordinary years, sufficiently dry."[12]

Destructive practices initiated by the Indians were not only continued but greatly extended by the white settlers. They continued for a time the bad prac-

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[9]Agriculture of Massachusetts, 4th Report (1841), p. 239.

[10]New England Quarterly, IX, 220.

[11]William Wood, New England's Prospect [1634] (Prince Society ed., Boston, 1865), p. 17.

[12]Timothy Dwight, Travels in New England and New York (New Haven, 1821 ed.), I, 103.

tice of annually burning over their woodlands, but the serious effects of this operation were quickly evident. According to Judd, "a law of Massachusetts in 1743, made to restrain such fires, says the burning of the woods greatly impoverishes the soil, prevents the growth of the wood and destroys much fence."[13] But in order to clear land for their tilled crops, the early colonists cut down and frequently burned over large areas of the natural forest. Although the first colonists apparently felt some restraint in the reckless destruction of their forests, those that came after them did not. Jared Eliot, writing in 1747, related, "They tho't themselves obliged to stubb all Staddle [grub out all small trees], and cut down or lop all great Trees; in which they expended much Cost and Time, to the prejudice of the Crop and impoverishing the Land."[14] An anonymous writer in 1775 wrote: "They not only cut down timber to raise their buildings and fences, but in clearing the grounds for cultivation they destroy all that comes in their way, as if they had nothing to do but to get rid of it at all events as fast as possible."[15]

The most serious consequence of the removal of all tree growth was not so much the loss of a considerable quantity of vegetative material itself as the destruction of the principal source of supply for the surface-accumulating layer of "vegetable mould" or organic matter, the only important reserve of soil fertility. The shallow-rooted, short-lived, rapid-growing farm crops were a poor substitute in this respect for the deep-rooted, long-lived, slow-growing forest trees.

For a time, newly cleared lands with their rich accumulation of humus were very productive. Referring to the newer settlements, the author of American Husbandry wrote in 1775: "Worse ploughing is nowhere to be seen, yet the farmers get tolerable crops; this is owing, particularly in the new settlements, to the looseness and fertility of old woodlands, which with very bad tillage, will yield excellent crops."[16] A few years later, in 1800, Timothy Dwight observed, "It is the universal tendency of the mould to produce great crops"[17]; and in another instance, "This mould is the manure, and ultimately the soil, of grounds long forested; and always yielding rich crops with very slovenly cultivation."[18] As long as the supply of soil organic matter lasted, good crops were grown, but when the store was exhausted, yields fell off badly. The burning over of timber lands, the continued removal of fertility through harvested crops, and the injurious effects of tillage, including the acceleration of the rate of decomposition of organic matter and greatly increased losses from leaching and surface erosion, were all important factors contributing to a rapid depletion of the soil's native fertility.

As early as 1637 one writer, speaking of the light sandy soils first cultivated in the vicinity of Cape Cod, wrote, "This soil is like your woodland in England, best at first, yet afterward grows more barren."[19] As indicated by Jared Eliot in 1747, very little effort was made to return to the land even part of the fertility which was removed or destroyed. " . . . the Land being new they depended upon the natural Fertility of the Ground, which served their purpose very well, and when they had worn out one piece they cleared another, without any concern to amend their land, except a little helped by the Fold and Cart-dung. . . . Our poor Land is so poor that it will not bear Turnips bigger than Buttons."[20]

[13] History of Hadley [Mass.] (New ed., Springfield, Mass., 1905), p. 98.
[14] Essays on Field Husbandry in New England [Boston, 1760] (1934 ed.), p. 1.
[15] American Husbandry, p. 61.
[16] Ibid., p. 60.
[17] Travels, II, 343.
[18] Ibid., I, 103.
[19] New England Quarterly, IX, 219.
[20] Field Husbandry, p. 29.

In 1853 C. L. Flint wrote that, "He [the early farmer] raised wheat until the land became too poor, and then he raised corn, and when it would no longer produce corn, he sowed barley or rye, and so on to beans."[21]

The same general pattern of exploiting the native soil fertility was followed in practically all areas of Massachusetts which were brought under cultivation, although, of course, it was not followed in all areas at the same time. A considerable period of time elapsed between the settling of Plymouth in 1620 and the founding of some of the hill towns in western Massachusetts during the latter part of the eighteenth century. The rapid destruction of humus did not worry the "exploiting" pioneer because he had no intention of settling permanently and cultivating the land. That the farmers who succeeded the pioneers were more careful and diligent in their farming operations is shown in a statement made by Timothy Dwight, "That which may be called the second set of planters may be considered as regularly superior to the first and the third, when there is a third, as regularly superior to the second."[22] Before better systems of farming were instituted, however, early cultural practices had destroyed most of the original store of soil humus and with it most of the soil's native productive capacity.

Besides severely impairing productive capacity, this destruction of humus had a pronounced deleterious effect on the soil's physical condition. Instead of the topsoil's being loose and friable and capable of growing good crops without much tillage, as many references indicate, more thorough tillage practices soon became necessary and grew increasingly difficult. The author of American Husbandry, in commenting on the "excellent crops" from "very bad tillage" on newly cleared land, says, "they are apt to suppose the same treatment will do on land long since broken up which is far from being the case."[23] The difficulties experienced in plowing where the mould layer was absent (possibly because of being burned over annually) were described by William Wood in 1634, when he wrote, "This ground is in some places of a soft mould and easie to plow . . . in other places so tough and hard, that I have seene ten Oxen toyled, their Iron chaines broken, and their Shares and Coulters much strained."[24]

(The effects of cultural practices and the importance of soil humus and their relationships to the physical condition of Massachusetts soils are points which will be further expanded in discussing the improvement of permanent and semi-permanent pastures.)

By no means all of the land which was exhausted was kept under cultivation; some was relegated to hay-land and pasture and much more was abandoned and allowed to revert to timber. In 1800 Timothy Dwight observed that "several specimens of an entire change in the forest vegetation are common in many, perhaps in all, parts of New England where the land has been cultivated, and again covered with wood."[25] This land abandonment probably began and progressed most rapidly on areas where physical handicaps were greatest. The presence of many rocks or conditions leading to poor drainage are physical handicaps which make cultivation a difficult, laborious procedure. When native fertility was depleted and the use of fertility supplements became obligatory, farmers naturally chose land which could be easily tilled. The introduction and increased use of machinery has also been a factor in the abandonment of steep and rocky land. The soils which are now being cultivated, therefore, are not necessarily inherently more fertile than many which have been abandoned, but many of the physical obstacles to cultivation are either absent or not objectionable. Some

[21]Mass. State Bd. Agric. 1st Annual Report (1853), Pt. I, p. 2.
[22]Travels, II, 469.
[23]American Husbandry, pp. 59-60.
[24]New England's Prospect, p. 14.
[25]Travels, II, 440.

exception may be made in the case of coarse sandy soils which have been abandoned and which offer no particular difficulties to cultivation, but even in this instance, it would seem that the cropping of sandy soils was given up principally because of poor water-holding capacity, and this is largely a physical relationship.

Summary

In concluding a discussion on the effects of cultivation on the character of Massachusetts soils, it should be pointed out that its influence was not important until the coming of the white settlers. Geology and climate, on the other hand, had largely accomplished their ends in developing most of the important characteristics of our soils long ages before any civilization was established. It should be further emphasized that some of the effects of geology and climate on the soils of Massachusetts, such as their sandy nature and their strongly leached profiles, play a greater role in both past and present-day fertility relationships than do early cultural practices. Even in the beginning, nature did not endow our soils with a large fertility reserve, and even this reserve was in a form which could be quickly and easily dissipated. We must not condemn the ways of our forefathers too strongly because, even if they had been less ruthless in exploiting the fertility of their land, the natural reserve would not have lasted indefinitely. Sections of the country where soils have been endowed by nature with far greater reserves of fertility than ours are now learning that these reserves are not inexhaustible, even under what are now considered good soil management practices.

The Massachusetts soils which are now being used for crop production may be characterized, before soil amendments are added, as being acid in reaction and deficient in nitrogen, calcium, potassium, magnesium, and to a lesser degree phosphorus. Soils of limestone origin or with a strong limestone influence may be less acid in reaction and contain some available calcium and magnesium, but they are deficient in other elements. All the cultivated soils are low in organic matter. Agricultural soils in Massachusetts, in short, may be characterized as productive but not fertile.

EARLY PASTURES IN MASSACHUSETTS

The first grazing areas in Massachusetts were the woods, which had previously been the hunting grounds of the Indians, together with scattered natural open meadow areas. Contrary to what might have been expected, the country was not a continuous expanse of dense forest for, as a result of being burned over annually by the Indians, extensive areas of open woods existed which provided considerable grazing. William Wood wrote in 1634 that "in many places, divers Acres being cleare, so that one may ride a hunting in most places of the land, if he will venture himselfe for being lost: there is no underwood saving in swamps, and low grounds that are wet . . . where the Trees grow thinne, there is good fodder to be got among the Woods."[26] The natural occurrence of open meadow areas is also indicated by the same writer, "There be likewise divers places neare the Plantations great broad Meadowes, wherein grow neither shrub nor Tree, lying low, in which places grows as much grass as may be throwne out with a Sithe, thick and long, as high as a man's middle." Graves wrote from Salem in 1629 that the country was "very beautiful in open lands mixed with goodly woods, and again open plains, in some places 500 acres, some more some less, not

[26]New England's Prospect, p. 17.

much troublesome to clear for the plough. . . . The grass and weeds grow up to a man's face . . . "[27]

Pasture Plants

Native Grasses

The native grasses included a few true grasses together with rushes, sedges, and other genera. Carrier[28] states that wild rye (Elymus sp.) was the most common of the native grasses, although Judd[29] says that three species of Andropogon, furcatus, nutans, and scoparius, were native to the intervales of the Connecticut Valley.

Some writers were quite enthusiastic about the merits of the native grass. "The worst that can be sayd against the meddow-grounds," wrote Wood in 1634, "is because there is little edish or after-pasture which may proceede from the late mowings . . . "[30] Other contemporary writers, on the other hand, were not nearly so enthusiastic. One of them wrote that the native grass is "so devoid of nutritive vertue, that our beasts grow lousy with feeding upon it."[31] Later, in 1747, Jared Eliot observed that, "Where there is no English Grass, it is difficult to make cattle truly fat."[32] Since none of the native species which were first utilized for forage were ever domesticated, one can safely conclude that they were not particularly valuable.

"English Grass"

At the time of the first settlements in Massachusetts, a number of good grasses and legumes were being cultivated in England, but, since clean seeds of grasses and clovers were not yet available, the stands were a mixture of many different species, including those of low as well as of high value. Sweepings of chaff from haystacks and haymows were used for seed, and it was in this form that the first "grass" seed was brought into Massachusetts. The expression "English grass" was a collective term regularly used to distinguish the introduced species—which usually included a mixture of blue grasses, rye grasses, bent grasses, fescues, and white clover—from the native grasses.

One writer speaks "of stocking lands from the gleanings of the floors and mangers of the barn 'where every plant, good and noxious, has left its seeds.' "[33] Judd reports that "the farmers of Rhode Island sowed hay-seed with chaff before 1647"[34] and also that William Pynchon of Springfield had "30 bushels of hay-seed" brought up the river from Hartford in 1650. According to the same author, "The General Court of Massachusetts by 1670 recognized three sorts of mowing, viz., salt marsh, fresh meadow, and English grass."

White Clover

Some of the introduced species became quickly naturalized and spread over wide areas. This was particularly true of white clover, which frequently appeared after land had been cleared and plowed far distant from places where it had been sown. According to Judd, white clover "was abundant in New Jersey in 1684, in New York in 1738 . . . and was observed by farmers in the new towns of

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[27]Judd, Hadley, p. 96.
[28]Lyman Carrier, Beginnings of Agriculture in America (New York, 1923), p. 27.
[29]Hadley, pp. 96-97.
[30]New England's Prospect, p. 13.
[31]New England Quarterly, IX, 219.
[32]Field Husbandry, p. 17.
[33]Mark Doolittle, Address to the Hampshire, Franklin and Hampden County Agricultural Society (Northampton, 1826), p. 12.
[34]Hadley, p. 362.

Hampshire, and of other parts of Massachusetts."[35] Governor Hutchinson of the Province of Massachusetts observed in 1760, that white clover seed was supposed to be in the earth in all parts of the country. Richard Parkinson in 1807 wrote that "The uncultivated land in North America also abounds with White Clover. The earth indeed seems almost to have been impregnated with its seed from the Creation as any kind of land when manured will produce it . . . "[36]

In view of the recent popularity of imported "Wild" White Clover strains from England, it is interesting to note that similar strains, probably the progenitors of the present English strains, were introduced into Massachusetts from England some three hundred years ago. Since our own "native" or "naturalized" white clovers have originated from the same original stock seed as the present English strains, many of the "native" strains should be quite similar in their growth characteristics as well as their performance to the present English strains.

Other Naturalized Species

Other pasture species which became quickly naturalized included Kentucky blue grass, Canada blue grass, the bent grasses, and to a certain extent some of the fescues. These grasses were somewhat more dependent on artificial seeding than white clover, but when once established they persisted almost indefinitely, particularly if soil conditions and grazing management practices were favorable. Belknap, in describing the clearing of new land in New Hampshire, states that "When the seeding with grass is neglected the ground becomes mossy and hard and must be ploughed before it will receive seed. . . . land which is intended for mowing, and which takes the common grass well at first, is seldom or never ploughed afterward."[37]

Pasturing in Common

Throughout the first settlements in Massachusetts, an extensive system of common pasturage was followed. Throughout the seventeenth century and much of the eighteenth, cattle, horses, sheep, hogs, and goats ranged the woods in every direction from the town proper, sometimes at large and sometimes in the care of village herdsmen.[38] These undivided pasture areas included the partially cleared plains and uncleared hills and mountain sides, frequently extending as far as twenty miles from the settlement itself. Dry stock, young stock, and hogs were pastured on the more remote areas, while working oxen, horses, and milk cows were pastured on the more accessible lands close to the village.

This woods pasturage, which consisted primarily of native herbs, weeds, and grasses, supplied most of the forage for all types of livestock with the exception of some aftermath or rowen grazing on common meadowlands. Bidwell and Falconer relate that "In the fall after harvest, on a day fixed by the town authorities, the barriers were taken down and the village cattle were allowed to pasture on the stubble. This yearly 'opening of the meadows' was an event in the life of the village."[39] They also report that such pasturage was regarded as especially valuable in preparing animals for the long winter and that pasturing rights on such areas were jealously guarded. Since many of the meadowlands were seeded down to "English grass," this would indicate that the superior feeding value of these introduced species was early recognized. Some of these meadowlands were

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[35] Hadley, p. 363.
[36] Richard Parkinson, The Experienced Farmer (London, 1807), p. 63.
[37] The History of New Hampshire (Boston, 1792), III, 100.
[38] Judd, Hadley, p. 102.
[39] P. W. Bidwell and J. I. Falconer, History of Agriculture in the Northern United States 1620-1860 (Washington, 1925), p. 22.

undoubtedly later used as pastures, and as such became the first high-quality pastures in Massachusetts.

Pasturing in common continued through the seventeenth century in the older towns and for most of the eighteenth century in the newer towns. By the beginning of the eighteenth century in the older towns, scattered lots of meadows and pastures came under private ownership. The same procedure of common pastures becoming private holdings was reenacted in the frontier towns as the eighteenth century progressed. The last common pasture to be broken up was on the Island of Nantucket in 1848. Up until this time, sheep had been given free range, but certain of the inhabitants objected so strenuously that they instituted legal proceedings, and according to one writer "then began the war which drove the sheep from the island and their value into the pockets of the lawyers."[40]

Agricultural Expansion in Massachusetts 1700–1750; 1750–1790

Notwithstanding the fact that grass-fed cattle were driven to Boston from the Connecticut Valley before 1655,[41] and also that salted meat and horses were exported from New England throughout the rest of the seventeenth and all of the eighteenth centuries,[42] the pasture crop received no particular attention during early colonial days except from a few individual farmers fattening beef in the Connecticut Valley and a few others operating dairies close to some of the larger coastal towns.

The period 1700 to 1760[43] was a period of expansion in which grain crops were the principal object of culture, and it was largely to obtain new land for grain production that frontiers were pushed back and new settlements established. About 1748 Jared Eliot observed that "Our Lands being thus worn out, I suppose to be one Reason why so many are inclined to Remove to new Places that they may raise Wheat."[44]

The pasture crop was largely incidental and no special effort was made to cultivate it. Land too poor to grow grain and meadows too badly "run out" to grow good hay were given over to pastures. Kalm about 1748 wrote:

> After the inhabitants have converted a tract of land into fields which had been a forest for many centuries together, and which consequently had a very fine soil, they use it as such, as long as it will bear corn; and when it ceases to bear any, they turn it into pasture for the cattle and take new corn-fields in another place where a fine soil can be met with, and where it has never been made use of for this purpose.[45]

The general lack of good meadow both for pasture and hay had a serious effect on the quality and health of the livestock. In 1747 Jared Eliot stated that "It is evident that the increasing stock of the Country hath out-grown the meadows, so that there is not hay for such a stock as the present increased number of people really need."[46] C. L. Flint records that "the death of their cattle from starvation and exposure was a very common occurrence"[47]; and an earlier author in 1775 observed that "the stunted diminutive size of all the cattle in North America to the northward, as well as in the southern colonies, shows plainly the great

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[40] Mass. State Bd. Agric. 13th Annual Report (1865), Pt. I, p. 256.
[41] Judd, Hadley, p. 369.
[42] Bidwell and Falconer, History of Agriculture, p. 44.
[43] P. W. Bidwell, Connecticut Academy of Arts and Sciences, Transactions, XX (1920-21), 241-399.
[44] Field Husbandry, p. 30
[45] American Husbandry, p. 106.
[46] Field Husbandry, p. 44.
[47] Grasses and Forage Plants (Boston, 1867 ed.), p. 184.

want of pastures: cattle will live and multiply in their woods, but they will never be cattle of any value and yielding a profit as unconsiderable as their worth."[48]

About the middle of the eighteenth century the potentialities of grass as a crop were generally seized upon, with the result that a period of rapid expansion took place between the years 1750 and 1790. Large areas of rough, rocky land generally unsuited for tillage were cleared, seeded to grass, and made to yield a most profitable crop. It was during this period that the "hill" towns, or "grazing" towns, as they were frequently called, in central and western Massachusetts were cleared and settled. Some indication of the rapidity with which this movement proceeded is found in the writings of a French traveler describing what he saw in western Connecticut in 1780: "I have never traveled three miles without meeting with a new settlement, either beginning to take form or already in cultivation"; whereas, he continues, "four years ago, one might have traveled ten miles in the woods I traversed without seeing a single habitation."[49] By 1800 Timothy Dwight had enthusiastically written, "Grass is undoubtedly the most valuable object of culture in New England. Grass grows spontaneously even on the driest grounds and luxuriantly on others."[50] Concerning the County of Worcester, he wrote, "Excellent neat cattle abound . . . and beef is perhaps nowheres better fattened upon grass. Swine also abound here. . . . Sheep are not very numerous. . . . Horses abound in every part of New England."[51] Speaking of the soils in western Massachusetts, he wrote that they "are generally fertile; and, particularly, are excellent grazing grounds."[52]

This period of pasture expansion is important because it was at this time that most of the permanent pasture area now found in Massachusetts was laid down. Some new lands were cleared after 1790 and the total area in pasture did not reach its maximum until 1875, but most of the land added to the total pasture acreage after 1790 was made up of hayland and cropland which was converted into pasture.

The various means by which much of this huge area (over a million acres) was cleared and seeded to grass can best be described by quoting direct from a current historian of the time. Jeremy Belknap, in his "History of New Hampshire" in 1792, gives clear and detailed description of how this was accomplished.

> Several ways of raising a crop on new land have been practiced. The easiest and cheapest method was originally learned of the Indians, who never looked very far forward in their improvements. The method is that of girdling the trees; which is done by making circular incision through the bark, and leaving them to die standing. This operation is performed in the summer, and the ground is sowed in August, with winter rye intermixed with grass. The next year, the trees do not put forth leaves, and the land having yield a crop, becomes fit for pasture. This method helps poor settlers a little the first year; but the inconvenience of it is, that if the trees are left standing, they are continually breaking and falling with the wind, which endangers the lives of cattle. . . . The more able sort of husbandmen, therefore, choose the method of clearing the land at first, by cutting down all the trees without exception. The most eligible time for the operation, is the month of June, when the sap is flowing, and the leaves are formed on the trees. These leaves will not drop from the fallen trees, but remain till the next year, when, being dry, they help to spread the fire, which is then set to the trees. This is done in the first dry weather of the succeeding spring, and generally in May; but if the ground be too dry, the fire will burn deep, and greatly injure the soil. There is therefore need of judgment to determine when the wood is dry enough to burn, and

48American Husbandry, p. 250.
49Bidwell and Falconer, History of Agriculture, p. 77.
50Travels, I, 48.
51Ibid., p. 376.
52Ibid., II, 267.

> the soil wet enough to resist the action of the fire; . . . if the land be intended for pasture only, the trees are cut down, and after the fire has destroyed the limbs, grass is sown, and the trunk of the trees are left to rot, which in turn, turns to good manure and the pasture is durable. . . .
> When the trees are burnt later in the summer, wheat or rye is sown, mixed with the seeds of grass, on the new land. The seed is scattered on the surface and raked in with a wooden or iron tooth rake, or a hoe. . . . Sometimes a crop of Indian Corn is raised the first year, and another of rye or wheat, the second year, and the land is sown with grass, which will turn it into pasture or mowing the third year. . . . It is not an uncommon thing for people, who are used to this kind of husbandry, to bring a tract of wilderness into grass for the first two crops; . . . Many husbandmen, in the old towns, buy lots of new land, and get them cleared and brought into grass, in this way, and pasture great numbers of cattle: the feed is excellent and the cattle are soon fattened for market.[53]

It is significant that over much of the area laid down to grass, the grass seeding was usually made directly after the forest cover was removed. In this way there was little opportunity for the store of native fertility to be dissipated either through crop removal or by soil erosion before the grass was established. The existence of a large area of permanent pasture in the State today is probably directly traceable to this practice, because it was observed years later that pastures which were established on cultivated land deteriorated much more rapidly than those which were laid down immediately after the removal of the forest trees.[54] Many of these original pasture areas produced many successive crops of grass without the aid of soil amendments before exhibiting any signs of exhaustion.

Importance of the Grass Crop to Nineteenth Century Agriculture

During most of the nineteenth century the grass crop, including both hay and pasturage, supported, either directly or indirectly, practically all types of agriculture in Massachusetts. Directly, grass supplied most of the feed for the beef, dairy, and sheep livestock industries, which flourished to a greater or less extent over the course of the century; indirectly, grass supported other types of agricultural enterprises in that it was the manure and by-products of the meat-processing industries which supplied most of the fertility for the successful production of tilled crops. The extensive raising of grain, the growing of different market-garden crops near large cities, and the development of such special crops as broomcorn, tobacco, and onions in the Connecticut Valley were made possible only because manure and various other by-products of animal origin were used as fertilizers in liberal quantities. Cattle were fed in the Connecticut Valley many years even after the cattle-feeding enterprise itself was unprofitable, for the sole purpose of producing manure for the culture of tilled crops.[55]

A clear recognition of the important role played by the grass crop in the agriculture of Massachusetts is contained in a report made by the pasture committee of the State Board of Agriculture in 1859. It read:

> The importance of the grass crop will be justly appreciated when it is remembered that no other crop equals it in value, not even the cotton crop of the South. It bears a similar relation to the other products of the farm that agriculture bears to the other interests and occupations of civilized communities. It is the basis of the farmer's success; it is his first, his continued and last dependence. His milk, butter, cheese, bread, meats, fruits, vegetables, the labor of his teams and his own labors, immediately or remotely, are derived from and sustained by his crops of grass.[56]

[53]The History of New Hampshire, III, 97.
[54]Mass. State Bd. Agric. 12th Annual Report (1864), Pt. I, p. 84.
[55]Ibid., 9th Annual Report (1861), Pt. I, p. 93; 13th Annual Report (1865), Pt. I, p. 300.
[56]Ibid., 7th Annual Report (1859), Pt. I, p. 24.

Of course other fertilizer materials were used to supplement manure, such as muck, wood ashes, gypsum, guano, bone meal, poudrettes (night soil), wool wastes, and other materials of greater or less fertilizing value; but it was not until commercial fertilizers as we now know them were introduced and made available in large quantities during the last quarter of the nineteenth century that grass ceased to be the major source of fertility for most forms of agriculture in Massachusetts.

The relationship of the grass crop to other crops and the serious situation which resulted when the grass crop began to fail is described by Goessmann in 1887, as follows:

> A serious falling off in the yield of the grass crop under the described circumstances necessitated a reduction in the farm live-stock, which in turn caused a decrease in the production of manure. Adding to this result the current practice of using the manure obtained from the feeding of the crops secured from the grasslands for the improvement of the ploughed lands, with scarcely any material assistance from outside sources of manurial substances, it is but natural that the productiveness of the former became in the course of time seriously impaired. A scanty supply of suitable manurial matter for the production of the crops raised is to-day universally considered the most fatal circumstance in any system of farming for profit.[57]

The fact that the grass crop was able to support the agriculture of Massachusetts for almost three quarters of a century is striking testimony to the efficiency of this crop as a conserver of soil fertility. With the use of only small quantities of supplemental fertilizers, this crop was able to extend the reserve supply of native or natural fertility over a long period of years. This is in sharp contrast to tilled crops, which, as already shown in the experience of the early colonists, exhausted the reserve of natural soil fertility in a relatively short period of years.

Pasture Deterioration and Exhaustion

In 1786 General Warren wrote that "Pastures are never manured and mowing lands seldom."[58] Since essentially the same situation continued on through the nineteenth century, it is not surprising to find that indications of pasture deterioration and exhaustion multiplied as the century progressed. Grass was an extremely efficient user of the reserve of natural fertility, but it could not go on producing indefinitely, for, as has already been explained, the reserve of natural fertility in most Massachusetts soils was not large. It is not surprising either to find that evidence of pasture deterioration is first found in the early settled portions of the State. Not only had the land been cultivated longer, but in many instances the soils in these sections were lighter and more quickly exhausted of their fertility, and in addition the early practice of making land into pastures only after cultivated crops were abandoned greatly shortened the life of the pastures.

The course of pasture deterioration may be followed by noting both the nature and the frequency of the comments which were made over the course of the nineteenth century. The following selected references, arranged chronologically, are an attempt to demonstrate this course:

Middlesex County, 1795.

> It is a prevailing errour to overstock both barns and pastures; in consequence of which, much of our grass land produces less than two, and some that has been wholly devoted to feed, less than one third of what it did 30 or 40 years ago . . . [59]

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[57]Mass. State Bd. Agric. 35th Annual Report (1887), p. 164.
[58]Bidwell and Falconer, History of Agriculture, p. 185.
[59]Mass. Historical Society Collections, 1st Series, IV (1795), 49.

State as a whole, 1841.

. . . in general nothing is more disreputable to the large majority of farmers throughout the State, than the conditions of their pastures.[60]

State as a whole, 1840-1850.

The pasture lands were increased more than 100,000 A., with scarcely any increase of neat cattle, and a reduction of 160,000 sheep and 17,000 swine.[61]

Middlesex County, 1853.

A large proportion of land, formerly improved as pasturage or tillage land, is now under a promising growth of young wood.[62]

Essex County, 1853.

Pasture lands for the past twenty years have been on the decrease. Except where they are ploughed and manured, they become mossy, run over to bushes, and are rapidly getting into wood.[63]

In many of our pastures it is now literally a struggle for life or death between the cow and the grass, from spring to autumn, and often neither has vitality enough to exult in a victory.[64]

State as a whole, 1853.

. . . in nearly one-half of the whole State there is a gradual and constant decrease, much of the land formerly tilled being given up to pasturage. In very many towns the number of acres in pasturage, also, is decreasing, many old pastures having become so poor as to be abandoned to bushes, or converted into woodland.[65]

State as a whole, 1859.

. . . the grazing lands of the State are greatly exhausted—feeding from one-sixth to three-sixths less stock than the same fed twenty-five to forty years ago.[66]

Worcester County, 1863.

It seems to be an established fact that the pastures in this vicinity are not as good as they were once. In them bushes and briars more easily take the places of some of the best grasses; they need ploughing oftener and require larger applications of manure to make them hold good, and it is said they need almost constant care and labor to keep them from running out.[67]

State as a whole, 1867.

Many of our old pastures have been stocked hard, time out of mind, and the grasses in them have been literally starved out, and grow thin of necessity, while, as the finer and nutritious grasses disappear, nature very kindly covers up the nakedness of the soil with moss, as an evidence of the effect, and not the cause of poverty. . . . Many of them are grown over with bushes and briers, and other equally worthless pests, till they carry but an animal to four or five acres, and often require twice that amount to keep an animal on foot, to say nothing of fattening him.[68]

State as a whole, 1872.

The Board of Agriculture have agreed to this: that there has been a great deterioration in the producing power of our pastures during the last fifty or one hundred years; that the time was when the hillsides of Massachusetts, those fields that are now our pasture-lands yielded large quantities of sweet nutritious grasses,—grasses which made butter, which made milk, which made cheese,—grasses which made beef of splendid quality. . . .

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[60]Agriculture of Massachusetts, 4th Report (1841), p. 398.
[61]David A. Wells, The Year Book of Agriculture (1855-1856), p. 215.
[62]Mass. State Bd. Agric. 1st Annual Report (1853), Pt. I, p. 70.
[63]Ibid., p. 69.
[64]Mass. Agricultural Societies Transactions (1853), p. 74.
[65]Mass. State Bd. Agric. 1st Annual Report (1853), Pt. I, p. 69.
[66]Ibid., 7th Annual Report (1859), Pt. I, p. 24.
[67]Ibid., 11th Annual Report (1863), Pt. II, p. 209.
[68]Flint, Grasses and Forage Plants, p. 355.

> but they have gradually deteriorated. . . . They will not carry the stock of former years; the quality of the grasses is not so good, and they will not produce so good cattle, or butter, or milk.[69]

Hampshire County, 1877.

> It seems to be a very important question here in New England, how shall we best improve our pasture-lands. . . . They were formerly cropped with wheat, rye, and corn, until reduced too low to make it pay. Then they were given up to pasture; and the constant drain upon them since, in the form of beef, butter, cheese, mutton and wool, has reduced them, so that they hardly pay for fencing and bushing, to say nothing of taxes, and interest on capital. There are hundreds of acres in my vicinity, on which I have seen good crops of grain growing, that are now abandoned to brush and wood; . . . [70]

State as a whole, 1884.

> . . . besides this, many farmers have been in the habit of cultivating their smoother land as long as it would bear a remunerating crop, applying as little manure as would possibly serve, and then laying it down to grass, under rye, oats, or barley, so as to get the last ounce of nutriment from the soil. This having been pretty well accomplished, a crop or two of hay is taken from it, and the land is then abandoned in an exhausted condition for a number of years to pasture, and from land thus treated cattle are expected to derive their support for four or five months; they go on it in lean condition in May, and come from it in November as poor as they went out. How to increase the productiveness of these pastures so that they shall not only hold their own, but carry more stock is the question.[71]

Pastures have continued to deteriorate since 1884 even up to the present, but since that date fewer references to their condition are available. One reason for this may be the much greater dependence since that time on commercial fertilizers as a source of fertility for tilled crops rather than on barnyard manure which came indirectly from the grass crop. Another reason is probably the increasing tendency during recent years to rely on periodically reseeded pastures and annual pastures for the main supply of pasturage rather than on permanent pastures. Still a third explanation may be the limited use in some sections of top-dressed fertilizers on permanent pastures, which in certain instances has greatly improved their condition.

Pasture Exhaustion and Land Abandonment

Permanent pasture was in the past and for that matter still is the last use to which land is put before it reverts to timber. That much of this land was badly depleted before being given over to pastures and that land abandonment quickly followed, is reported from Franklin County in 1865. Speaking of general practices in "hill towns", this report stated:

> The main feature in these towns is expressively termed 'skinning,' cutting off wood and timber, selling hay, and sometimes what little grain they raise, to the river farmers, 'running' their mowing lands and then turning them into pasturage. In short, taking all they can from the land and returning nothing. . . . In many of the hill towns population is diminishing. Many houses are unoccupied, and going to decay, and there is a general lack of thrift and enterprise among the farmers.[72]

By 1872, according to another writer, "The border settler in New England twenty years ago is close to the forest now. Half-made clearings are again growing up, and log-cabins are tenantless. Hills once covered with sheep are moss-

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[69] Mass. State Bd. Agric. 20th Annual Report (1872), Pt. I, p. 202.
[70] Ibid., 25th Annual Report (1877), Pt. I, p. 299.
[71] Ibid., 32d Annual Report (1884), p. 83.
[72] Ibid., 13th Annual Report (1865), Pt. I, p. 307.

grown. . . . "[73] Some years later, in 1888, a western hill-town farmer complained that the chief difficulty in sheep raising "is not so much on account of dogs as on account of the difficulty in keeping sheep in your own pasture. The abandonment of so many farms in our mountain town has left a large tract of land open [and] there is no place to confine the sheep. . . . "[74]

This reversion of permanent pasture land to timber land is still proceeding at a fairly rapid rate, though not as fast as during the latter part of the nineteenth century.

The Causes of Pasture Deterioration

The causes of pasture deterioration were obvious and quickly recognized by many agricultural leaders. In 1859 the pasture committee for the State Board of Agriculture reported:

> It is known to all who have investigated this subject, that all pastures which have been constantly and closely cropped for many years, without receiving suitable returns, must of necessity be greatly exhausted of those substances which, in the economy of nature, are appropriated to the growth and support of bone and muscle, and to the production of milk; and that thorough renovation can be effected only by restoring those substances to the soil.[75]

Some years later, in 1872, Levi Stockbridge, in a stirring address before a meeting of the State Board of Agriculture, declared:

> We have all agreed on saying that the cause of this deterioration is perfectly clear and apparent; that it is because we have been building up animal structures, or manufacturing cattle products which have been taken away from the fields that produced them, never to return; that where all the products have not been transported to the market, we have taken the milk for the manufacture of butter and cheese, and the manurial qualities that were contained in the milk left at home have been given to other fields instead of being carried back to the pastures that produced them; and that we have been sending away tens of hundreds of tons annually from these New England pastures in the form of phosphates, and sulphates in the bones of animals, and nitrogen in their muscles and tissues; it has gone in one sweeping current down to our great cities; and then, owing to the most abominable and wasteful system of sewerage which has been adopted, it has been carried to the sea and been lost. We have agreed that this is the cause of the deterioration of our pastures.[76]

C. L. Flint, secretary of the State Board of Agriculture, summed up the situation in 1877 by declaring that:

> The great besetting sin of New England farming has been, that we have robbed our grass-land to feed our hoed crops and our arable lands. We have done it persistently almost from the first settlement of the country.[77]

It was also observed that milk cattle exhausted pasture more rapidly than either beef cattle or sheep. This was noted as early as 1859 by the pasture committee of the State Board of Agriculture[78] and also by Flint[79] in 1867. Therefore the shift from beef cattle and sheep to dairy cattle, about the middle of the nineteenth century, was an important factor in accelerating the deterioration of pasture lands.

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[73]Ibid., 20th Annual Report (1872), Pt. II, p. 77.
[74]Ibid., 36th Annual Report (1888), Pt. I, p. 72.
[75]Ibid., 7th Annual Report (1859), Pt. I, p. 25.
[76]Ibid., 20th Annual Report (1872), Pt. I, p. 202.
[77]Ibid., 25th Annual Report (1877), Pt. I, p. 121.
[78]Ibid., 7th Annual Report (1859), Pt. I, p. 27.
[79]Grasses and Forage Plants, p. 362.

Early Attempts at Pasture Renovation

It would seem that, if the seriousness of pasture deterioration were appreciated and its causes understood, as appears to have been the case, something would have been done to correct the situation. The answer is that something was done. Many different systems of pasture renovation were tried out from time to time during most of the nineteenth century and many of them were highly successful. The difficulty was that none of these systems, even though highly successful, was ever widely adopted. A variety of materials was used from time to time, including ashes, gypsum, lime, bone meal, guano, manure, compost, and muck, both as top-dressings and as amendments worked into the soil by tillage.

Henry Colman[80] in 1841 tells of a particularly successful farmer in Essex County who regularly ploughed, manured, and seeded his pasture lands. In 1851 the chairman of the pasture committee of Essex County recommended the use of gypsum as a top-dressing "on such land as is benefited by it," as the "best and cheapest way of renovating pasture lands."[81] The pasture committee for the State Board of Agriculture[82] in 1859 advised using bones combined with wood ashes if manure were not available. They also suggested top-dressing old pastures with "from one to two bushels of plaster per acre: or twenty-five bushels of wood ashes per acre, where plaster refuses to operate"; but in most instances the committee favored ploughing and reseeding as oppcsed to top-dressing. They recognized, however, that ploughing "will be found of little avail—except to destroy weeds and bushes—without a suitable application of manure." They suggested the following plan for the renovation of old pastures:

> Set apart four or five lots of convenient size; plough and plant No. 1 with corn, applying enough manure to produce a good crop. The next year sow the same with wheat or barley, and stock down to grass. Plant and treat No. 2 with the same manure, and so continue, planting one lot and stocking down one lot each year, until all are stocked down to grass. At the end of six years the five lots will have been completely renovated, and the same course commenced for a second turn. Thus the system may be indefinitely continued, yielding an unbroken succession of remunerative crops and pasturage of the finest quality.

In the light of present-day knowledge of soils and soil fertility in Massachusetts, this committee in 1859, in the opinion of some at least, were sounder and more logical in their recommendation than perhaps they themselves realized.

There is considerable evidence that tillage was rather widely practiced as well as recommended as a means of pasture improvement. A report[83] frcm Plymouth County in 1865 stated that a considerable portion of the corn and most of the rye that was raised was grown on pasture land "to rid it of bushes and briars." The supervisor for pasture improvement for the same county in 1866 declared that "the process of mowing bushes is merely conservative, having, like all conservatism, no higher aim than that of keeping 'things as they are.' For permanent improvement more radical measures are necessary, and the plough, where it can be used, is the most approved agency for initiating them."[84]

A farmer in Worcester County in 1877 described a system that he had been following to improve his worn-out pasture land, which consisted of removing the stones, ploughing, cultivating, manuring, and reseeding. "In this way," he wrote, "I expect to restore my pastures to that abundant supply of sweet, milk-producing grass that was produced so abundantly in former years."[85]

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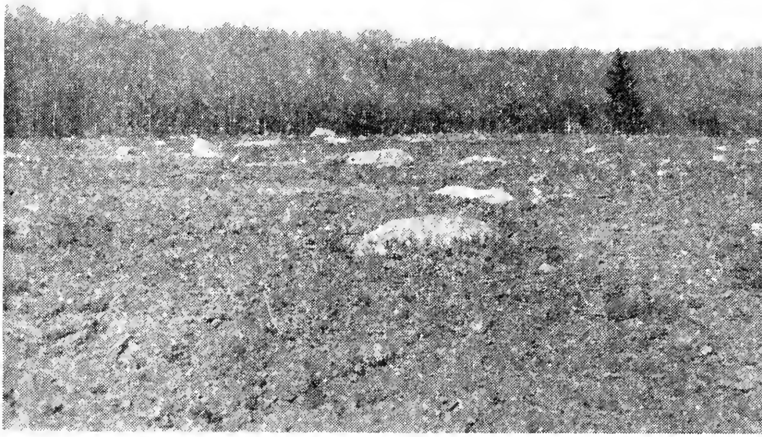
[80] Agriculture of Massachusetts, 4th Report (1841), p. 398.
[81] Mass. Agricultural Societies Transactions (1851), p. 45.
[82] Mass. State Bd. Agric. 7th Annual Report (1859), Pt. I, p. 27.
[83] Ibid., 13th Annual Report (1865), Pt. I, p. 280.
[84] Ibid., 14th Annual Report (1866), Pt. II, p. 19.
[85] Ibid., 25th Annual Report (1877), Pt. I., p. 299.

The Difference Between the Two Pastures Shown Above is Largely a Difference in Soil Fertility.

Above: A "run-out" pasture which is rapidly reverting to brush and trees.
Below: A well-fertilized semi-permanent pasture supplying excellent grazing to a large herd.

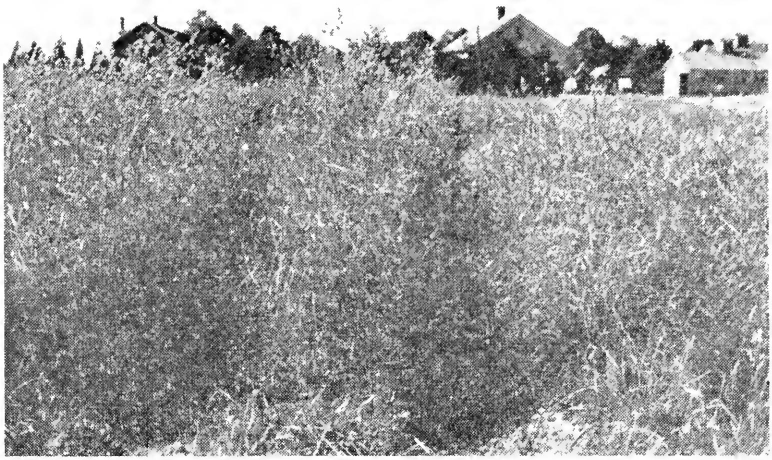


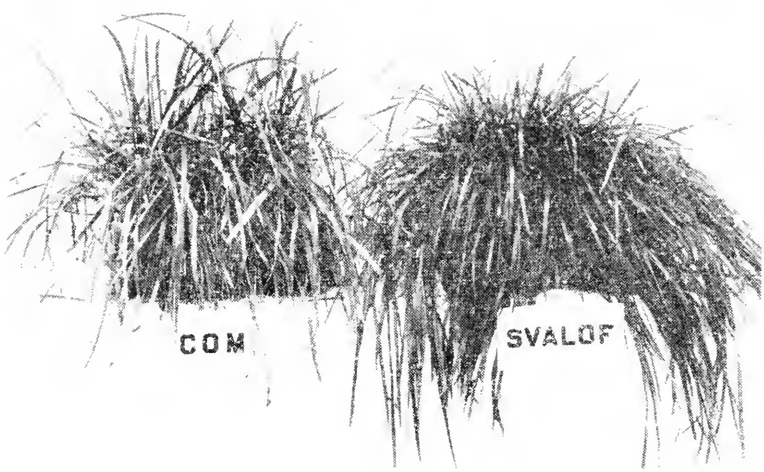
Where Land is too Stony to Plow, a "Bog" Harrow is Sometimes Used to Facilitate Seedbed Preparation.

Above: A field which has just been tilled with a "bog" harrow.
Below: A "close-up" of the machine.

Above: A strongly podzolized soil profile located near Wellfleet on Cape Cod, showing a well-developed A_2 horizon.

Below: Alfalfa requires a high level of soil fertility. Where a top-dressing of potash has been applied annually, a good stand of alfalfa remains after four seasons; but where no potash was applied, severe winterkilling took place at the end of the third season.





Grass Strains
Differences Between "Strains" may be of Real Practical Importance.

Above: The short-growing orchard grass strain on the right is a late leafy hay type which can be grown satisfactorily with alfalfa. It is much more desirable than either of the two coarse-stemmed early-maturing strains on the left.
Below: The Svalof early meadow fescue on the right is apparently immune to leaf rust whereas the "commercial" meadow fescue on the left is very susceptible.

But notwithstanding the pasture improvement recommendations of the agricultural leaders and the success achieved by some of the best farmers, pasture improvement practices were never generally adopted. Secretary Flint reported in 1853 that "In some places some real and positive improvement has been made—in others no pains have been taken even to prevent deterioration."[86] And Secretary Russell, in a spirit of resignation, some years later reported that "These pastures are the constant topic of agricultural discussion. 'How to improve the fertility of our pasture,' is a standing question of clubs and institutes, only answered in theory."[87]

Why Pasture Improvement Failed

It would appear that one of the most important reasons for the failure of all attempts to prevent a general deterioration of pasture lands during the nineteenth century was the great scarcity of manures of all kinds. As has already been pointed out, most of the available supply of barnyard manure was used on the arable land to maintain satisfactory yields of tilled crops. Since most of this manure was made on the individual farms by feeding the grass crop of the farm to livestock, it was obvious that enough manure could not be made available to supply both the grass and the cultivated crops. The farming system was one of a slow transfer of the fertility of the grassland over to the tilled land. Until some outside source of fertility could be tapped either to maintain the fertility of the grasslands or to provide the fertility for the tilled lands, a gradual deterioration of the grasslands was inevitable. To a limited extent outside sources of fertility did exist, but the supplies were limited and the materials were usually expensive. Wood ashes, gypsum, guano, bone meal, muck, composts, and various mill wastes were all used, but the quantity of plant food material which either was available or could be profitably used was wholly inadequate to meet the needs.

Another important factor was the existence of large areas of cheap grasslands. Farmers discovered that it was much cheaper to clear or buy and exploit new lands than it was to renovate old land. Land was relatively abundant and values were low. For example, in 1865 pasture lands could be bought for as low as two dollars an acre, and seldom was the price more than twenty-five dollars per acre.[88] Together with cheapness of the land were low standards of productivity for both land and livestock. In 1841, a pasture of thirty acres which would keep twelve cattle was considered an "excellent" pasture.[89] A cow which produced two or three thousand pounds of milk in a year was a satisfactory producer. These standards of production are less than half present-day standards.

Still another important consideration was the widespread belief among farmers that, since pastures would produce something even on poor lands and would also withstand a great deal of abuse in their management, this, then, was the most profitable way to handle them. F. H. Storer wrote that "one fundamental conception in the mind of many New England farmers is, that the land devoted to pasturage upon any given farm should either be poor land or rocky land or land so inaccessible that it could hardly be used for any other purpose. . . . "[90] Unfortunately this conception has continued in the minds of many farmers all over the country down to the present day.

A final factor which undoubtedly played some role in earlier as well as in recent

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[86]Mass. State Bd. Agric. 1st Annual Report (1853), Pt. I, p. 70.
[87]Ibid., 29th Annual Report (1881), Pt. I, p. 17.
[88]Ibid., 13th Annual Report (1865), Pt. I, p. 122.
[89]Agriculture of Massachusetts, 4th Report (1841), p. 79.
[90]Agriculture in Some of Its Relations with Chemistry (7th ed., New York, 1910), III, 593.

times is the slowness with which pasture lands frequently respond to treatment and the difficulties involved in measuring the magnitude of the response. It may take one or more years for top-dressed materials to produce their full effect, and reseeded pastures require most of one full season's growth before they are well established. As a result, farmers have become somewhat impatient with pasture improvement practices and have not fully appreciated their worth.

The historical development of agriculture in Massachusetts was accurately summarized fifty years ago by one Professor Whitcher, when he wrote:

> First we have the so-called period of inexhaustible fertility, when it was thought that the soil would continue to yield abundant crops indefinitely, without the application of fertilizer. Then we have the period of exhaustion, when the soil has become exhausted of plant food and will no longer produce a good crop. Then comes the third period, the period of renovation, when we are asking how we can overcome the results of the errors of previous methods.[91]

Pasture lands in Massachusetts have already passed through the first and second periods and they are just entering the third period at the present time.

PRESENT DAY PASTURES — THEIR CULTURE AND MANAGEMENT

Since agricultural leaders first attacked the problem of pasture improvement in the nineteenth century, conditions have materially changed. Fertilizer substances which were either non-existent or scarce and expensive in former days are at present available in practically unlimited quantities and at relatively low cost. Our present-day knowledge of the soil and plant sciences, although by no means exhaustive, nevertheless offers plausible explanations for phenomena which puzzled our nineteenth century predecessors. It is desirable, therefore, to examine the observations and conclusions of these earlier workers, in the light of present-day theories and information. It would be a serious omission if the early work in the field of pasture improvement were ignored or slighted, because the apparent accuracy of much of this work is amazing.

The following discussion is an attempt to integrate that which appears to be the best in nineteenth century thinking with that which appears to be the best in twentieth century thinking as it relates to the problem of pasture improvement in Massachusetts. The problem is considered from the standpoint of the four principal cultural factors which determine the productivity and usefulness of pastures in Massachusetts—the soil, the grazing system, the pasture plant, and the climate.

The Soil

In reviewing the history of pastures in Massachusetts, the one significant fact which stands out above all others is that the soil, in terms of soil fertility, has been the chief limiting factor to successful pasture culture.

A satisfactory explanation of why this was true may be found when one considers the fundamental nature of the soils themselves, a subject which has already been discussed in some detail. If this explanation is true for the past, and the writer on the basis of his studies and experience thoroughly believes that it is, then soil fertility must still be one of the most important limiting factors in pasture culture since it is practically impossible to change the fundamental character of a soil.

Before discussing soil fertility, a definition or an explanation of what is meant

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[91]Mass. State Bd. Agric. 38th Annual Report (1890), p. 15.

by the term is desirable. Unfortunately no simple, concise definition can be given because soil fertility is "a complicated and multi-dimensional problem." Soil fertility is not simply a matter of abundant supplies of nitrogen, calcium, potassium, and phosphorus, but includes many other chemical, physical, and biological relationships of the soil as well. Soil fertility really consists of a large number of factors operating favorably toward the production of a crop. Some of these factors are known, others as yet little understood, and probably many others still unknown. Perhaps the best definition of soil fertility which can be given was formulated many years ago by one Nathan Bowen in a letter to Jared Eliot in 1761, when he wrote, "The grand secret of the planters Art, seems to be to Supply the plants with a Sufficient & proper Food, water and air in due proportion & Time. This Art being well understood and practiced by him, will give the fruit of his Labour to his Sattisfaction if he have any Reason at all."[92] A high level of soil fertility implies a capacity on the part of the soil to "satisfy simultaneously and continually during the whole time of the growth of a plant its maximum demand in water and food." A low level of soil fertility or infertility, of course, implies the opposite condition.

Soil Fertility and Yields

To point out the relationship of soil fertility and crop yield may seem superfluous since such a relationship should be perfectly obvious. Within certain limits this has been generally recognized with most other field crops but not with pastures. The fact that pasture yields are extremely difficult to measure and the fact that pastures will withstand a great deal of abuse in their cultural management and still produce something have partially obscured the direct relationship which exists between soil fertility and herbage yields. Some appear to go so far as to assume that, although such a relationship exists with tilled crops, with pastures it is relatively unimportant and the most economical way, if not the best way, to manage a pasture is to starve it. Those who wish to fit the plant to the soil and not the soil to the plant and who are searching for a high-yielding, nutritious, palatable pasture species which will thrive on "run-out"soils fall in this group.

Soil fertility influences pasture yields in two important ways. The first is through the direct relationship which exists between the level of soil fertility in a pasture and the productivity of whatever pasture species may be present. Any pasture species, irrespective of its particular growth habit or soil adaptation, is much more productive at high than at low fertility levels.

The second way is through the close correlation which exists between the soil fertility level and the botanical composition of the pasture vegetation. This is more noticeable in semi-permanent pasture than it is in permanent pastures. In the former, highly productive species, such as alfalfa or Ladino clover, will maintain themselves and remain productive as long as soil conditions are favorable; but when soil conditions become less favorable, they are supplanted by less productive species and disappear altogether. In permanent pastures, a similar succession of lower fertility species supplanting higher fertility ones is easily observed as soil fertility levels fall. As permanent pastures become exhausted, bent grass and low-growing white clover supplant blue grass and tall-growing white clover; poverty grass supplants both bent grass and white clover; while mosses and woody shrubs eventually succeeded by forest trees complete the whole succession.

It has long been observed that many of the more productive pasture species demand a relatively high level of fertility before they will grow satisfactorily. John Worlidge observed in 1675 that "Land too rich for Corn, cannot be too rich

[92]Field Husbandry, p. 208.

for [red] clover."[93] In 1747 Jared Eliot stated that "If Land be too poor, it [clover] will not grow."[94] Recent experience with Ladino clover in Massachusetts has shown that the superior yielding capacity of this plant and its phenomenal ability to make a quick comeback after grazing can be realized only through the maintenance of high levels of soil fertility. When this high level declines, as it inevitably does three or four years after seeding, this species usually disappears. Alfalfa, another high yielding species, reacts similarly, and there is mounting evidence to show that certain of the grasses behave in the same manner.

Soil Fertility and Feed Quality

In addition to producing more feed, fertile soils produce better feed. This fact was recognized many years ago by G. L. Clemence, when he stated that "A ton of hay gathered from a third of an acre has more of the elements of animal growth than has a ton raised upon an entire acre. . . . that one acre has been able to produce only one ton to the other's three, is evidence in itself that it is lacking in the elements of plant and animal growth."[95]

In recent years, coincident with generally declining fertility levels of many of the hay and pasture sections of the country, there has been an increase in nutritional diseases traced to mineral deficiencies in forage crops. Nutritional anemia in cattle has been traced to a deficiency of iron in forage produced in certain sections of southeastern Massachusetts.[96] Elsewhere in the country other nutritional disorders or diseases have been variously traced to mineral deficiences of calcium, phosphorus, and copper and still other elements.[97]

Albrecht has expressed the situation thus: "Crops can make themselves only from what is offered by the soil. Animals can make themselves only from what is offered them by the crops as feed, and thus in the final analysis, the animals reflect the fertility of the soil."[98]

Palatability, another important factor in feeding any type of livestock, is closely associated with feed quality. Feeds low in nutritive value are seldom palatable. Wheat straw is an extreme example, yet the herbage supplied by many of our "run-out" pastures in midseason is little more palatable. Indeed. it is no coincidence that the hay and pasture plants most sought after by stockmen for their nutritive value and for their palatability require a fertile soil.

Soil Fertility and Resistance to Disease and Winter Injury

Just as the health of animals is dependent upon nutritious forage, so is the health of plants dependent upon a fertile soil. This conception is another idea that is not new. Years ago, W. H. Bowker in 1880 stated that, "It has been demonstrated over and over again that a healthy plant will withstand disease, and a healthy plant means one that is properly fed from beginning to end."[99] Professor Stone some years later wrote that "a condition of health is the natural or normal thing with the plant, and that if we as cultivators do our part by making the condition right for the normal development of the plant, many of these troublesome problems of disease are thereby solved in advance. . . . The first essential in the prevention of plant disease is to supply the plant with the conditions for its best normal development."[100]

In recent years, closer studies of nutrient deficiency symptoms in plants have

[93]Systema Agriculturae (London, 1675), p. 26.
[94]Field Husbandry, p. 18.
[95]Mass. State Bd. Agric. 38th Annual Report (1890), p. 297.
[96]Journal of Dairy Science, XXI (1938), 59-68.
[97]National Fertilizer Association, Pamphlet No. 129, 1941.
[98]Fertilizer Review, XIII (1938), No. 5.
[99]Mass. State Bd. Agric. 34th Annual Report (1886), p. 209.
[100]Ibid., 54th Annual Report (1906), p. 22.

shown that many physiologic disorders or diseases are directly associated with a deficiency in one or more essential nutrient elements. Some of these so-called "deficiency diseases" have been found affecting forage crops in Massachusetts. A characteristic chlorotic condition of the plant leaves has been identified with a deficiency of soil magnesium. More recently, a yellowing of the leaves of alfalfa, particularly in the second crop, has been definitely associated with deficiency of soil boron.

Winter injury, particularly with some of the leguminous crops, is another important trouble which has long been associated with soil fertility. In 1888, for example, the Massachusetts Experiment Station reported[101] that the unfertilized plots of alfalfa, red clover, alsike, perennial rye grass, and meadow fescue showed serious winter injury, whereas fertilized plots did not. It was reported from Rhode Island in 1898[102] that the liberal use of lime had resulted in good crops of red clover on soils where clover had "formerly winterkilled nearly every year."

Much evidence has been obtained in Massachusetts recently to show that additional potash applied as top-dressing to fields of alfalfa will greatly reduce winter injury and thereby prolong the life of the stand.[103] In this case potassium appears to have been the limiting fertility factor to what was otherwise a satisfactory level of fertility. Since alfalfa is a heavy feeder on potassium and since Massachusetts soils are naturally low in potassium, this pronounced response to a potash fertilizer is readily conceivable. In Rhode Island, lime or more likely calcium was directly associated with winter injury while in Massachusetts it was potassium. It would seem, therefore, that a deficiency of any important nutrient element might so weaken a plant as to render it susceptible to winter injury. The weakening of a plant by injury from certain disease organisms might also have the same effect.

Healthy plants are hardy plants and to produce healthy plants the soil must be capable of delivering to the plant an adequate supply of all essential plant nutrients. Plants like animals perform at their best only when given a balanced as well as a plentiful "diet."

Factors in Soil Fertility Maintenance

Practically all available evidence indicates that adequate levels of soil fertility are just as important to the pasture crop as they are to any other productive crop. Pastures offer some difficulties in this respect which do not exist with tilled crops. The fundamental principles of fertility maintenance are essentially the same in both cases, but because of differences in cultural procedure, the practical application of these principles is more difficult.

Fertilizer Materials.— As previously discussed, the soils of Massachusetts are naturally low in available quantities of many essential nutrient elements, including calcium, magnesium, potassium, phosphorus, and nitrogen. Therefore, for these soils to supply the pasture crop with an "adequate and balanced diet," the supplies of these necessary elements must be periodically replenished.

Lime.— The need for calcium was early recognized and materials supplying this element were among the first soil amendments used in this country. Jared Eliot in 1747 wrote of a type of marl which he tried and "found it equal to good dung."[104] The use of this material on grasslands was mentioned as early as

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[101] Ibid., 36th Annual Report (1888), p. 517.
[102] Ibid., 46th Annual Report (1898), p. 189.
[103] Mass. Agric. Expt. Sta., Bul. 355 (1939), p. 19.
[104] Field Husbandry, p. 17.

1761.[105] During the latter part of the eighteenth century the use of gypsum or land plaster was initiated with much success and it was used extensively throughout most of the nineteenth century. The use of limestone was common by 1820 in sections where it was abundant, but its general use was not extensive until later on in the nineteenth century when processing and transportation facilities were improved and costs had been lowered. In 1838 Colman reported that the cost of lime in Massachusetts prevented its use to any considerable extent except in the limestone regions. Many of the principal benefits of lime were recognized by the same author when he spoke of its use as "neutralizing the acids which render a soil sour and unproductive; in converting insoluble into soluble matter and in thus preparing the vegetable matter in the soil for the food of the plants and bringing it into condition by which it can be taken up by their roots."[106]

Recent studies by Albrecht[107] indicate that calcium is even more important in the nutrition of plants than was formerly thought. Not only must calcium be considered as a very essential element in itself, but plentiful supplies of calcium in the soil are essential for the efficient utilization of other nutrient elements such as potassium and phosphorus. These same studies have shown that available calcium is the important consideration and that soil pH to a large extent is more or less incidental. Therefore the use of materials which supply available calcium in adequate quantities is of utmost importance. Limestone is probably the cheapest and most effective source of calcium, and in Massachusetts where soils are also deficient in magnesium, a dolomitic limestone is preferable. It must also not be overlooked that many fertilizer materials carry calcium as an incidental part of their composition and that calcium in this form may serve a very useful purpose in supplying the needs of the crop.

Potash and Phosphates.— The early and extensive use of wood ashes as a "manure" indicates an early recognition of a deficiency of soil potassium in Massachusetts. Jared Eliot in 1747 observed "Ashes is allowed on all hands to be some of the best Dressing or Manure for Land; it enriches much and lasts long but the misery is we can get but little."[108] A hundred years later Colonel Wilder declared, "I have never used any manure on my soils that would produce such a wonderful effect as ashes. . . . I am of the opinion that there is no mineral manure that we need so much upon our soils here in New England that have been long under cultivation as potash."[109] Recent experimental results on the beneficial effects of potash in stimulating the growth of white clover in permanent pastures, in greatly benefiting stands of alfalfa and Ladino clover, and in increasing the yields of hay mixtures, merely substantiate the keen observations of Colonel Wilder.

Historical references to the importance of phosphates are not nearly so frequent as they are for potash and lime. However, the use of "bone manure" before the middle of the nineteenth century is evidence that the addition of phosphates was beneficial. More recently crop responses from phosphate fertilization have not been so pronounced as they have from potash fertilization probably because of the comparatively light, or sandy nature of most Massachusetts soils. Such soils invariably respond to potash fertilization before they do to phosphate fertilization. Moreover, the phosphorus content of most commercial fertilizers has been proportionately high ever since they came into extensive use so that phosphorus needs in general have been met. It must not be construed,

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[105] Field Husbandry, p. 160.

[106] Agriculture of Massachusetts, 2d Report (1838), p. 11.

[107] Soil Science Society of America Proceedings V (1940), 1-16.

[108] Field Husbandry, p. 43.

[109] Mass. State Bd. Agric. 17th Annual Report (1869), Pt. I, p. 47.

however, that liberal applications of phosphate fertilizers need not be continued, for many of our most desirable forage crops, particularly the legumes, are ravenous consumers of phosphorus as well as of calcium, magnesium, and potassium and they must have adequate supplies of all of these elements.

Nitrogen.— Organic matter is the natural repository of soil nitrogen. The original reserve of nitrogen in Massachusetts soils was contained in the accumulated layer of organic matter or vegetable mold and as long as appreciable quantities of this original supply of organic matter persisted in the soil, there was no great need for additional nitrogen. As soon as the supply was exhausted, however, another source of nitrogen was necessary. For many years this need in pastures was supplied principally by the legume, white clover. Where legumes constitute a substantial part of the vegetation today, they can still be relied upon to supply a considerable portion of the necessary nitrogen. Where grasses predominate, on the other hand, the use of nitrogen fertilizers is obligatory, since grasses to be productive must have large quantities of this element.

Minor Elements.— The lack of some of the minor elements is indicated by the more frequent occurrence in recent years of a number of different "deficiency diseases." To prevent this occurrence, it now appears that, in addition to magnesium, boron and perhaps other elements must be supplied to many Massachusetts soils.

Organic Matter.— Soil organic matter, the material which played such an important soil fertility role in the past in Massachusetts, is at the present time a very important factor in soil fertility relationships. The principal difference between present and former times is that today the nature of organic matter and its behavior are better understood and the desirability of periodically replenishing the organic matter supply of cultivated soils is more widely appreciated.

Soil organic matter is one of the most active constituents in the soil. If present in adequate quantities in soils well supplied with plant food it serves to hold certain of the more soluble nutrients in such a way as to make them readily available to growing plants but yet to prevent excessive losses through leaching. This function is also carried on by colloidal clay, an inorganic material, but since the clay content of most Massachusetts soils is quite low, the action of organic colloids in this respect is of much greater importance.

A great many of the favorable effects of organic matter result not from its mere presence in the soil but from its being continually broken down into its simpler constituents. Under favorable circumstances complete breakdown of this material releases quantities of plant food nutrients which can be readily taken up by growing plants. In this way not only nitrogen is released but also calcium, potassium, magnesium, and many other essential elements.

The relationship of decomposing organic matter to the development and maintenance of good soil structure is important, but this subject will receive fuller treatment in the discussion on tillage.

In spite of the many "positive" effects of soil organic matter, Albrecht,[110] in a recent enlightening discussion on this subject, points out that organic matter under certain conditions may be injurious to plant growth. Such can be the case if plant nutrients are physically held through absorption so securely as to be unavailable to growing plants. Injurious effects can also result if, during the process of complete breakdown, the microorganisms which bring about this transformation are not supplied with a "well-balanced bacterial ration." The microorganisms may withdraw nutrients from the soil solution and from the

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[110]Soil Science, LI (1941), 487-494.

organic material itself to such an extent that the crop plants actually suffer from an unbalance or a deficiency of one or more essential elements. A temporary nitrogen deficiency is frequently induced when large quantities of carbonaceous materials are plowed under without sufficient nitrogen to promote both the decomposition of the organic matter and the satisfactory growth of the crop. If available supplies of other elements are limited, deficiencies or perhaps an unbalance of essential plant food nutrients may also be induced as a result of the decomposition process. This is likely to be the situation in soils which had been badly depleted of their available essential minerals before a quantity of organic matter was plowed under.

The need for supplementary nitrogen to promote the decomposition of certain types of organic matter is generally recognized and steps are usually taken to provide it; but the need for additional quantities of supplementary mineral elements to promote decomposition is not generally recognized and this may account for some of our now unexplainable difficulties in crop production. For a number of years many farmers in Massachusetts have frequently had difficulty in producing satisfactory tilled crops following immediately on land which has lain for several years in hay or pasture. Since the common hay and pasture species are capable of reducing fertility of a soil to a low level and since the general practice has been to let such a condition develop, immediate difficulties in producing crops on "run out" hay or pasture land might be expected. Unless the needs of both the microorganisms and the crop can be satisfactorily met, the crop will certainly suffer. The succeeding crop may be adequately fertilized, but it may require a considerable period of time for the fertilizers to act and re-establish satisfactory soil fertility relationships.

The most satisfactory solution of this problem would be to prevent such a condition from developing. If satisfactory levels of soil fertility are maintained in hay and pasture lands, not only will greatly increased yields of better hay or pasture herbage result but the succeeding crops in rotation will benefit from the "positive" effects of decomposing organic matter instead of suffering from its "negative" effects. In fact, one of the most satisfactory means of replenishing the supply of organic matter in a cultivated soil is through the periodic production of a well-fertilized sod crop. Stapledon has recently written that, "It is an axiom to my mind to say that a ley [sod] is a good preparation for any crop,"[111] but this will only be true when the fertility levels maintained in sod lands are comparable to those maintained in other crop lands.

Tillage.— Over three hundred years ago Lord Bacon wrote that "Old ground, that hath been long unbroken up, gathereth mosse; and therefore husbandmen use to cure their pasture grounds, when they growe to mosse, by tilling them for a yeare or two."[112] Since the time of Bacon, much evidence has accumulated which definitely indicates that grasslands, at least on soils similar to those in Massachusetts, must be periodically plowed and reseeded if high levels of productivity are to be maintained. Jared Eliot, in describing grasslands in Connecticut, noted that, "The Experienced Farmers say that their Grass Ground thus Ploughed Once in Five Years mends the Land in this way."[113] Bordley, writing about grasslands in eastern Pennsylvania in 1801, said, "It is of great advantage to turn up the ground, shift its surface, and bury the sods of grass."[114] This is in direct contradiction to the idea now occasionally expressed, though not proved, that a layer of organic matter at the surface of the ground is necessary for some of the

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[111]Plough-Up Policy and Ley Farming (London, 1939), p. 75.
[112]Storer, Agriculture III, 612.
[113]Field Husbandry, p. 64.
[114]Bordley's Husbandry (Philadelphia, 1801), p. 10.

shallow-rooted permanent pasture plants—principally native white clover—to thrive. Bordley continued, "The expense of seed for renewing grass is thought too much of by farmers. It is a trifle, when opposed by the advantages gained."

Many observations on the benefits of tillage to grasslands have also been recorded in Massachusetts. Henry Colman in 1841 wrote:

> Without a question, where land has become, as it is termed, 'bound out', the sward matted, and the herbage fine, small and stunted, much would be gained by simply turning it over, keeping the sward unbroken, harrowing it and freely sowing grass seed upon it, especially with the application of ashes or plaster, or some other alkaline substance . . . to get the greatest yield, an occasional manuring, and the cultivation of the soil so as to break up its tenacity and expose it freely to the influence of sun and air are indispensable. The coarse grasses will soon come in again if the land is not cultivated and manured.[115]

The following quotation, taken from the Massachusetts State Board of Agriculture report for 1871, on the necessity of periodically plowing grasslands is typical of a number which appear from time to time from 1853 through to 1906:

> If land is moist and thoroughly stocked, it may be kept in good condition for several years by a judicious top-dressing. But my own experience is that top-dressing cannot be applied to high lands with so good a result. Manage as we may, in from three to five years the crop grows less, the wild grass begins to creep in, and from five to eight years the land needs turning over and reseeding.[116]

Many experiments in top-dressing both hay lands and pasture with fertilizers have been carried on from time to time in Massachusetts. A marked improvement has usually been obtained in both quality and quantity of feed produced, but in no instance have the results indicated that top-dressed applications of fertilizer materials were nearly as effective as plowing, fertilizing, and reseeding. In experiments reported by W. P. Brooks[117] from the Massachusetts Station in 1903, hay top-dressed with manure yielded something over 5,600 pounds per acre; while hay land which was manured, plowed, and reseeded, yielded 10,000 pounds per acre. Although much encouraged by his first results from the use of top-dressed fertilizers, he finally concluded that their use could extend the useful life of hay sods only a year or two.

Levi Stockbridge, one of the keenest agricultural men of his day, whose judgment concerning practical agricultural matters in Massachusetts was unsurpassed, declared in 1872: " . . . my experience and observations are, that there is no grass-land in Massachusetts but what ought to be ploughed once in ten years."[118] There is a striking similarity in Stockbridge's statement to one made in 1939 by Sir George Stapledon, one of the world's leading pasture authorities, discussing the grasslands of England. Sir George writes:

> In this country, and even on the very best grassland soils, I do not believe there is a single field that would not benefit from periodic breaking. I do not say that it would be possible or desirable, to plough into every single acre of permanent grass in the country: but this is my point.
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> The sods below all permanent grass, if not becoming actually matted, at least attain to a sort of "pot bound" condition after the lapse of a sufficient number of years; on the best soils and under the best and most intelligently grazed swards this condition may take thirty, forty, fifty or sixty years to develop. On poorer soils, and under less intensive grazing ten to fifteen years will be long enough for an advanced pot-boundness to show itself. Some soils cannot carry decent grass for longer than four to six years . . . the concensus of opinion everywhere is that animals are

[115]Agriculture of Massachusetts, 4th Report (1841), p. 239.
[116]Mass. State Bd. Agric. 19th Annual Report (1871), Pt. II, p. 22.
[117]Hatch Expt. Sta. (Mass. Agric. College), 16th Annual Report (1904), p. 145.
[118]Mass. State Bd. Agric. 20th Annual Report (1872), Pt. I, p. 197.

healthy in proportion as the pastures are kept tolerably near to the plough—are not, in short, of too great age in sward.[119]

John Orr, another prominent British authority on grass farming, writes:

Nothing will establish British agriculture on such a sound basis as the use of the plough for the growth of grass. . . . For the quick and effective introduction into the soil of raw materials from which grass is made, and for its speedy production in finished form, the plough is necessary.[120]

Such expressions of expert opinion concerning the best grasslands of England, for years regarded as models of perfection in grassland management, are certainly interesting if not revolutionary. If permanent pastures do not represent the best pastures of England where soil and climatic conditions are generally favorable for their best development, then prospects are indeed poor for making first-rate permanent pastures out of the large area of run-down pasture land in Massachusetts, where both soil and climate are far less congenial.

The Case for Tillage in Pasture Culture.— Why is tillage essential to high productivity levels in grasslands? If both historical evidence and present-day expert opinion agree that the periodic plowing and reseeding of grasslands are prerequisite to high productivity levels, then there must be some good fundamental explanation. In recent years experimental work has been carried out in various parts of the world which has supplied some scientific evidence to support early observations. Although still more scientific evidence may be necessary to provide a full explanation, the following discussion in the light of present information supplies a plausible if not a totally correct interpretation.

It was early observed in Massachusetts that adequate soil tillage for cultivated crops was directly associated with soil moisture relationships. "The very Dews will enter his pulverized Fields, with a larger Blessing than a large Shower can give his Slovenly Neighbour because his ground is not fit to receive it or Retain it,"[121] wrote one Nathan Bowen, in 1761. Later it was observed that moisture relationships in grasslands become steadily poorer as the character of the sod itself depreciates. The surface becomes hard and rather impervious to rainfall, the water-holding capacity is reduced, and even the moisture already present in the soil appears to be lost from the surface more readily by evaporation.[122] To substantiate some of these observations, experiments reported recently from New Jersey[123] showed that the water loss, as total run-off, from a continuously grazed pasture plot was four times as great as that from a grass-legume seeding and even greater than that from the corn plot. Recent work on the evaporation of water from bare soil surfaces, carried on at the Missouri Station,[124] indicates that, for some soil types at least, moisture from below the surface may be continually lost through evaporation until the available moisture supply is depleted to a considerable depth. It appears, therefore, that, as a sod becomes older, particularly on sandy soils, certain physical relationships of the soil become progressively less and less favorable to plant growth.

In order to determine just what factors were responsible for reduced yields from aging sods, experiments were carried out in Germany on soils similar to those in Massachusetts. In one series of experiments[125] certain physical properties of the soil were measured in natural meadowland and similar areas which had been plowed and reseeded. It was found that in the plowed land the water-

[119]Plough-Up Policy and Ley Farming, p. 21.
[120]Scottish Journal of Agriculture, XX (1937), 3-40.
[121]Field Husbandry, p. 208.
[122]Mass. State Bd. Agric. 58th Annual Report (1910), p. 12.
[123]Soil Conservation, V (1940), 256-258.
[124]Private Communication from C. M. Woodruff, Dept. of Soils, Mo. Agric. Expt. Sta., 1941.
[125]Zeitschrift für Pflanzenernährung Düngung und Bodenkunde, A XXXII (1933), 278-301.

holding capacity of the soil was increased, particularly on mineral soils naturally low in organic matter; the air content was over 50 percent greater; and the organic matter content was appreciably lower. In another series of similar experiments,[126] some of these same measurements were taken over a period of years and the results correlated with yields of hay. The hay yields on the plowed and reseeded areas fell off progressively as the values for water-holding capacity, soil structure, and content of soil air of the reseeded areas approached those for natural meadow soils. It is difficult to say just which factor was the most important in raising the production of the reseeded plots because it is difficult to separate the effect of improved nutrient relationships and water-holding capacity in the newly seeded areas from the effects of better aeration or some other changed relationship. It is likely that in the case of light, mineral soils, greater supplies of plant nutrients and increased water-holding capacity were important factors, but improved soil aeration may also have been very important. Recent investigations on the importance of oxygen in plant nutrition definitely suggest this possibility. Hoagland and Arnon believe that, "the factor of oxygen supply and of carbon dioxide removal from around the roots may sometimes limit nutrient absorption by plants, even when availability of nutrients, in a chemical sense, is not limiting."[127] Similar views have recently been expressed by Shive.[128]

In the second series of German experiments, efforts were made to increase the yield of the natural meadowland by the use of various fertilizer top-dressing materials. There was some increase in yield from several of the treatments, but in no instance did the yield even approach that obtained from the reseeded plots. The fact that factors other than a lack of plant food nutrients were important in limiting yields, explains why simply supplying these nutrients did not restore hay yields. Perhaps lack of an adequate supply of available oxygen and an excess of carbon dioxide were important.

Further light is thrown on the subject of tillage by results from Russian experiments which have been reviewed by Russell.[129] The Russians have found that the structure of a soil is improved not by the presence of raw organic matter in the soil but by its decomposition, and that the greater the rate of decomposition the greater will be the improvement in soil structure. This explains why, although a large amount of organic material accumulates in a soil under a continuous sod cover, soil structure actually deteriorates together with other factors influencing plant growth, such as moisture-holding capacity and soil aeration. It also shows why a well-developed sod, when plowed under, may produce so many desirable effects. As Lindsay-Robb writes —

> The age-old implement the plough is still the most efficient cultivator on the farm. . . . It is the only implement that enables a farmer to release and cash the 'frozen' fertility that has accumulated since the pasture was established. The effect of cultivation on arable land—which incidentally commences with the plough—is well known, and it is equally true of established grassland.[130]

Fertility Improvement and Maintenance in Permanent Pastures

Although one might conclude from the foregoing discussion that it is practically impossible to maintain satisfactory fertility levels in a grass sod for more than a few years, such an interpretation is not altogether correct. By following suitable practices, fair yields of moderately good feed can be produced in permanent

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126 Pflanzenbau, XIV (1938), 241-264.
127 Soil Science, LI (1941), 431-444.
128 Ibid., pp. 445-458.
129 Imperial Bureau of Soil Science, Tech. Communication No. 37, (1938).
130 University of Pretoria (South Africa), Series No. 1, Bul. 36, p. 29.

pastures, provided natural soil conditions are favorable. Following is a critical discussion of certain widely publicized "systems" for bringing about permanent pasture improvement.

Factors Influencing the Growth of Natural White Clover.— Since the success of several methods for treating permanent pastures depends upon the successful growth of natural white clover, it would be well to consider some of the important factors which influence its growth.

Moisture.— Without question, moisture is the most important factor influencing the prevalence of natural white clover in permanent pasture sods. "Indeed, it depends so much upon a general distribution of rains through the season," wrote Flint in 1867, "that when they are sufficiently abundant it comes in profusely even where it was not observed in other years, and hence such seasons pass under the term of 'clover years.' "[131] An adequate supply of moisture is so important for this very aggressive but shallow-rooted plant that any permanent pasture-improvement program which depends largely on the growth of natural white clover for its success, should be confined only to those pasture areas which have satisfactory moisture relationships throughout most of a normal season.

Mineral Nutrients.— An adequate supply of mineral nutrients is just as important as soil moisture in maintaining a vigorous growth of white clover. At the present time most permanent pasture soils in Massachusetts which have not been limed and fertilized are too deficient in a number of the necessary plant food elements, particularly calcium and potash, to support a good growth of white clover. If adequate quantities of these elements are supplied through top-dressed lime and fertilizers to soils with good moisture relationships, an abundant growth of natural white clover will invariably result.

Competition from Associated Grasses.— A third important factor influencing the prevalence of natural white clover is the vigorous growth of the accompanying grasses.[132] This competition frequently exists in pastures which have been improperly grazed or which have been heavily fertilized with nitrogen fertilizers and then improperly grazed. If grass is not subdued in pastures of moderately low levels of fertility, the white clover will seriously suffer because under such conditions only the low-growing forms will thrive and such forms offer poor competition for tall-growing grasses.

Competition from grasses is always serious following periods of drought. The effects of dry weather are always much more severe on the clover than on the grass. The succulent leaves and stems of the clover usually dry up completely and the plant dies, whereas the grasses usually remain dormant throughout the dry period and then begin growth again as soon as growing conditions are again favorable. These grasses, stimulated by the nitrogen released from the dead clover plants, then make very rapid growth which in turn makes survival difficult for any clover plant which may have escaped the drought. It is now generally believed that the effects of nitrogen fertilizers on clovers are indirect. The nitrogen stimulates the grasses and the grasses in turn, unless closely grazed, tend to crowd out the clovers.

"Hard" Seeds.— The "spontaneous" appearance of natural white clover wherever and whenever soil conditions are favorable, is probably explained by the abundant production of "hard" seeds. Early observations have shown that some of these "hard" seeds will germinate after remaining many years in vials

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[131] Grass and Forage Plants, pp. 188-189.

[132] B. A. Brown, Journal American Society of Agronomy, XXXI (1939), 326-332.

filled with water.[133] That such seeds can live for a long time submerged in water, gives some indication as to how long they might lie dormant in the soil before germinating. More recent experimental work tends to support these earlier observations.[134] What evidently happens is that a great many seeds are lying dormant in the soil and that a few of them germinate every year. If fertility conditions are favorable these few plants make an extremely rapid, spreading growth. One single plant under favorable circumstances may spread out in a radius of from two to three feet in one season's growth. The limiting factor to growth may be the lack of one or more of the fertilizer elements, or it may be lack of moisture; but if these factors are eliminated, this remarkable "spontaneous" growth of natural white clover invariably results. The seeds of natural white clover appear to have been universally distributed over the whole of New England and the sudden appearance of this species can occur almost anywhere.

Top-dressing with Lime and Fertilizer.— The use of only lime and superphosphate has been reasonably successful in sections where silt loam and clay loam soils are found and also on lands recently cleared of timber where the soils have a high content of organic matter. Since neither extensive areas of silt loam and clay loam soils nor lands recently cleared of timber are found in Massachusetts, this type of treatment for permanent pastures has met with only limited success here. Some of the heavier soils in Franklin and Berkshire counties do give a moderate response to treatments with lime and superphosphate, but most of the lighter soils both in these two counties and elsewhere in the State do not.

The application of potash in addition to lime and superphosphate has produced moderately good results on a much greater variety of soil types than has just lime and superphosphate. This is to be expected since it has already been shown that the potassium deficiency in many Massachusetts soils is more acute than phosphorus deficiency. The response of all clovers to application of potash in Massachusetts has long been observed.[135]

If moisture relationships are such that a complete mineral treatment cannot be relied upon to induce a good growth of natural white clover, nitrogen must be added to the top-dressing mixture. Grasses must have plenty of nitrogen to produce a satisfactory growth, and if a legume cannot be relied upon some other source must be provided. Permanent pasture grasses are more widely distributed than natural white clover in Massachusetts, with the result that there is a considerable area of land which will respond to a complete fertilizer. It is by no means uncommon in badly depleted pastures for a complete fertilizer to actually stimulate the growth of natural white clover. Quite often nitrogen alone is applied on permanent pasture in the early spring to provide early spring grazing. Although this provides an economical source of early spring feed, nitrogen alone without additional use of lime and mineral fertilizers will merely hasten the depletion of essential soil minerals and thereby hasten pasture deterioration.

Detailed recommendations for the kinds and amounts of lime and fertilizer materials to use, together with a description of how and where they may be applied, are available in several current publications.[136]

Fertility Improvement and Maintenance in Semi-Permanent Pastures

The fertility problem in semi-permanent pastures is handled much the same as for any tilled crop. The land is plowed, then adequately fertilized using suitable fertilizer materials including barnyard manure if available, and finally worked

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[133]Mass. State Bd. Agric. 54th Annual Report (1906), p. 150.
[134]International Seed Testing Association Proceedings, X (1938), 93-122.
[135]Wm. P. Brooks, Hatch Expt. Sta. (Mass. Agric. College), 6th Annual Report (1894), p. 9.
[136]Mass. State College Extension Leaflet 150 (1940).

up into a satisfactory seedbed and seeded. On many areas used for pastures of this kind, it is difficult to use the ordinary plow because of rocks and stones. A tillage implement known as a "bog" harrow is sometimes used under these circumstances with quite satisfactory results. Any tool which will break up and pulverize the top five or six inches of soil can be employed; although for the best decomposition and utilization of the old sod it should be completely turned under.

The use of annual top-dressings of mineral fertilizers on pastures of this type is recommended in order to maintain high levels of productivity. Moderate applications of fertilizers at seeding time, followed by annual applications, usually result in a more efficient use of these materials than if large applications are made at seeding time only. As is the case with permanent pastures more detailed information is contained in current publications.[137]

The Grazing System

"Manure right, sow right and manage the grazing animal wrong and you are nowhere," writes Stapledon[138] in emphasizing the importance of grazing management. It is only within the last few years, with the extensive growing of Ladino clover pastures, that the importance of grazing management has begun to be understood and appreciated in Massachusetts.

With old run-down permanent pastures the yield depends more upon the weather and on fertilizer practices than on the grazing system employed. It has always been difficult to demonstrate any marked improvement or benefit from a rotational over a continuous system of grazing on permanent pastures. Grazing management becomes important only as the potential productive capacity of a pasture increases. The productive capacity of most of our permanent pastures is too low for them to show much benefit from rotational grazing. In other words, the greater the productive capacity of a pasture, the greater the need for controlled grazing.

Historical

The need for exercising some control in the management of grasslands has long been recognized in Massachusetts. Almost two hundred years ago Jared Eliot wrote: "It will be best to take out the Sheep at the latter end of August that so what English Grass there is, may make coat for the ground before Winter . . . "[139] The principles of rotational grazing were also early understood and the adoption of rotational systems of grazing advocated. Jn. Turner in 1761 wrote concerning early colonial grazing practices:

> Another Error, I mention, is, that in Pasture Ground we leave open too large a Piece to feed upon, in Proportion to the Number of creatures to feed; as it is frequently the case, for one Cow to range on five or six Acres of good Land at once, whereas by Division Fences in two Acre Lots, the same Tract would maintain three Cows; . . . There is another advantage I have experienced in Division Fences, that in a wet Year I have saved several Lots for Mowing which my Creatures did not want the Feed of; and, had my Pastures lain in common, they would have been trampled down and useless.[140]

Other references[141] to the use of rotational or "on and off" systems of grazing appear from time to time, but at no time until recently was the system adopted

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[137]Mass. State College Extension Leaflets 175 (1937); 144 (1939).

[138]Fourth International Grassland Congress, Great Britain, Report (Aberystwyth, 1937), p. 1.

[139]Field Husbandry, p. 19.

[140]Ibid., p. 155.

[141]Doolittle, Address to the Hampshire, Franklin and Hampden County Agricultural Society, (Northampton, 1826), p. 11; Mass. Agricultural Societies Transactions (1853), p. 9; Mass. State Bd. Agric. 20th Annual Report (1872), Pt. I, p. 38.

to any great extent. In the early days when pasture land was plentiful and grazing was good, farmers saw little need for expending additional time and money to rotate the grazing of these pastures. Later, when these pastures were "run out," it made comparatively little difference whether grazing was rotated or not. Controlled grazing practices are at present much more important in the management of good semi-permanent pastures than in most permanent pastures.

The Principles of Grazing Management

About the only semi-permanent pasture species whose grazing management has been studied in Massachusetts is Ladino clover. Although the requirements of other species may vary, it is likely that many of the best management practices for Ladino clover will apply to many of the other legumes at least. Some of the most important elements of grazing technique include the following:

Alternate Grazing.— Ladino clover will not withstand continuous, close grazing. Vigorously growing Ladino clover produces large leaves borne on long upright-growing stems. If these leaves are continually removed, the plant cannot maintain a large enough leaf surface to carry on its normal life functions. Its growth becomes less vigorous and before long it is crowded out altogether by some less productive, less desirable species. Continuous grazing probably results also in much mechanical injury to the heavy, succulent runners which spread over the ground, and in this manner reduces plant growth. Therefore, Ladino clover pastures must be rested periodically to allow the plants to recover from the effects of grazing. A grazing period of one week to ten days appears to be the best for Ladino clover. This permits the removal of most of the vegetative growth which was present at the beginning of the grazing period, but not of much of the new growth which occurs during that period.

Keeping animals on the pasture only a few hours a day during the grazing period is another desirable practice, for it reduces mechanical injury to the plants and compaction of the soil through tramping. This latter factor is particularly important in the spring and during wet weather.

Even Grazing.— Unless a good pasture is uniformly grazed it deteriorates rapidly. The undergrazed areas quickly become less palatable and are therefore shunned more than ever, while the overgrazed areas become more palatable in contrast and are therefore still more heavily overgrazed. Heavy stocking over a relatively short grazing period is the best way to prevent the development of this condition. A good Ladino clover pasture usually requires from eight to twelve cows per acre to graze it evenly in a grazing period of one week to ten days. Occasionally the use of a mower after grazing may be necessary to remove uneaten clumps.

Late Fall and Early Spring Grazing.— Grazing good pastures late in the fall frequently prevents the storage of adequate food reserves in the roots of plants like Ladino clover and often results in severe winter injury. Grazing early in the spring before good growth has started or while the ground is soft is also frequently injurious. Pasture plants must be permitted to make their early spring growth unmolested, to enable them to maintain high productivity levels later in the season.

The Pasture Plant

The third principal factor which directly influences the productivity, feeding value, and general usefulness of a pasture is the kind and type of plants which thrive there.

Not only the total productivity of a pasture but also its seasonal productivity,

the ability to supply herbage during the hot summer as well as during the spring and autumn, is closely associated with the nature of the plant cover. This phase of the pasture problem, like that of grazing management, is relatively new and it is one in which rapid progress is now being made. Therefore, it is not possible at this time to present a full or conclusive discussion.

Permanent Pasture Species

The pasture plants most commonly found in permanent pastures are Kentucky bluegrass and white clover in the best pastures; variable percentages of bluegrasses, bent grasses, fescues, and native white clovers, together with a variety of weed species, in the poorer ones. Although the species composition of most poor permanent pastures can be definitely improved by following suitable fertilizing practices, the best that can be hoped for without plowing and reseeding is a good stand of Kentucky bluegrass and native white clover. These two plants, although a good source of grazing during the spring and fall, are invariably a poor source during midsummer. The clover is particularly susceptible to injury from drought, while bluegrass grows very slowly during hot weather. The result has been that permanent pastures reach high levels of production in spring and autumn and fall to very low levels during midsummer.

Semi-Permanent Pasture Species

Because of the serious limitations inherent in the common permanent pasture species, a number of other grasses and legumes have recently been used in pasture seedings. In practically all cases with these plants, however, it is necessary to plow and fertilize before seeding; and in most cases, even though the plants are perennial in nature, a good stand will not last for more than three to five years. Consequently the period of maximum usefulness of such pastures is limited and they are called semi-permanent pastures.

Several of these newer legumes and grasses, have proved to be definitely superior to bluegrass and native white clover. If soil fertility relationships are favorable and the grazing is controlled, total yields of herbage are much larger and, what is more important, seasonal fluctuations in yield are smaller. Production is maintained at fairly high levels even during the hot summer months when good grazing is usually quite scarce.

Of the newer pasture legumes tried in Massachusetts, Ladino clover has been used with the greatest success over a fairly wide range of soil conditions. In other sections of the country alfalfa is showing some promise as a pasture plant, but because of the nature of the soils the extensive use of alfalfa in Massachusetts as compared to Ladino clover is unlikely, especially as alfalfa lacks some of the qualities of a good grazing plant. Many of our soils are shallow with sandy or gravelly subsoils and as such are not well suited to a deep-rooted, strong-feeding crop like alfalfa, while with other soils the water table is too high for satisfactory growth. Ladino clover, which compares favorably with alfalfa in yielding ability, is a surface feeder with large numbers of small roots which develop principally in the plow layer of soil. It is a comparatively simple matter to maintain adequate supplies of mineral nutrients in the plow layer through adequate fertilizer practices, but it is difficult to make up mineral deficiencies in the subsoil layers.

The newer grasses have been given only limited trials in Massachusetts and most of these have been experimental. Of the species thus far tested, brome grass, meadow fescue, orchard grass, and certain types of rye grass appear to show the most promise. With most of these species, particularly with orchard grass, many different strains have been developed, some of which are much more suitable for pasture purposes than others. Many of these different strains are now undergoing careful test, seeded alone and in mixtures, and it is likely that plant breeders will produce still better strains as time goes on. Indications are that some superior

pasture strains of the above-named species will soon be available for general use. However, a word of caution needs to be sounded regarding the use of these new and improved strains of both grasses and legumes. Important though they may be, they are no substitute for soil fertility and, to a considerable extent, will accentuate rather than reduce the need for controlled grazing. This is a condition which plant breeders and farmers alike should not overlook.

Pasture Seeding Mixture

Little can be said concerning the matter of seed mixtures until many of the newer pasture strains have been given wider testing. A few conclusions, however, do appear justified. It is generally conceded that a suitable combination of grasses and legumes appears to be desirable from the standpoint of maintaining not only high levels of production but also high feeding values. A number of species which have regularly been included in pasture mixtures since mixtures were first used in Massachusetts, are likely to be eliminated in the future. For example, it seems unnecessary to include the seed of Kentucky bluegrass and white clover in a pasture seeding mixture when these species will come in voluntarily and dominate the vegetation in a few years whether they are seeded or not. Red top is another grass which will probably be used less extensively. The growth habits of this grass appear to be incompatible with those of some of our better pasture species. It does not grow well with Ladino clover and when associated with alfalfa, excessive lodging frequently results. To include red top with a seeding of either Ladino clover or alfalfa appears to be unwise.

The whole question of pasture seeding mixtures is one which is now being carefully studied and investigated and it is probable that still more important changes will be made.

The Climate

Weather is perhaps the most important factor affecting the productivity and usefulness of a pasture but since nothing can be done to control it directly, it has been considered last. Temperature and rainfall are closely associated not only with seasonal production of pastures, but with total production as well. In wet seasons, herbage yields rise to high levels and in dry seasons they fall to low levels. There are several ways, however, of indirectly ameliorating the unfavorable influence of the weather.

One important means is the maintenance of high soil fertility levels. Fertile soils in good tilth with a dense, rich vegetative cover are much less affected by adverse weather conditions than are depleted soils with hard, baked surfaces which will support only a scanty plant cover. "It is a rule that admits of no dispute," wrote J. E. Russell almost sixty years ago, "that well-manured lands best withstand drouth."[142]

A second means is the use of desirable pasture plants which are heat and drought tolerant, are cold resistant, and are productive even though seasonal weather conditions are somewhat unfavorable. In 1853 J. C. Gray wrote "As no human power can change our climate, and as there seems no prospect of any amelioration of its severe winters or its parching droughts, it is an obvious dictate of common sense, to select such plants for cultivation, whether annual or perennial, as can best resist its fierce extremes."[143]

If, after careful attention has been given to the soil and plant factors, further consideration is given to a well-conceived farm management program, the prob-

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[142]Mass. State Bd. Agric. 30th Annual Report (1882), p. 10.
[143]Ibid., 1st Annual Report (1853), Pt. I, p. 162.

lem of weather can be largely solved. This management program may call for a large semi-permanent pasture acreage which would supply most of the normal grazing requirements. Any excess could be used for the production of hay or grass silage. It might involve the normal cutting of the first crop for hay or silage with grazing of the regrowth or aftermath during midsummer. This practice appears now to be particularly promising. During protracted dry summer periods the hay or silage previously harvested can be used as supplementary feed and thereby lighten the grazing load of the suffering pastures. All these suggestions, of course, imply carefully controlled grazing, since controlled grazing is necessary in achieving maximum performance from a good pasture.

To most effectively reduce the fluctuation in pasture yields due to weather, one must fertilize his soil adequately, select and manage his pasture plants judiciously, and plan farming operations carefully.

SUMMARY AND CONCLUSIONS

In the foregoing treatment of pastures an attempt has been made first to review the historical background of pastures in Massachusetts and second to analyze the principal agronomic factors involved in their present day culture and management. In actual practice of course, other factors, principally economic, must be taken into consideration, but many of these vary in importance from time to time and so are difficult to discuss or evaluate. Taking into account the soil, the plant, and the weather, the following conclusions seem justified concerning the production of pasture forage in Massachusetts.

Permanent Pastures

It seems likely that permanent pastures will never again occupy the position of prominence they once held. The limited reserve of soil fertility which carried them through many productive years of existence has long since been exhausted. If these "run-out" pasture soils could be restored to their original state of fertility by the superficial use of fertilizers, this condition would not be so serious; but such is not the case. The gradual depletion of these old sods meant not only the loss of mineral nutrient elements alone; it meant the destruction of the virgin accumulation of organic matter and a degradation of the soil's physical condition. Surface-applied fertilizers are fairly effective in correcting soil mineral deficiencies, but they accomplish little toward improving the physical condition of the soil. In many permanent pastures the slopes are either so steep or rocky or already so encumbered by brush growth that it is practically impossible to make fertilizer treatments. Permanent pastures also present a difficult problem with respect to organic matter because, while a sod may build up organic matter in the soil, this material is not effectively utilized unless it is turned under and allowed to decay. As a final consideration it must be pointed out that pasture standards have probably risen in recent years. A permanent pasture which may have been wholly satisfactory for beef cattle or sheep one hundred years ago is quite inadequate for the average dairy herd of today.

What place, therefore, will the permanent pasture have in present-day pasture systems? This question cannot be answered definitely because conditions will vary from farm to farm, but certain generalizations can be made. In pastures where the soil is retentive of moisture and where moderate regular applications of fertilizers will maintain a good bluegrass-white clover sod, much good economical grazing may be had during the spring and fall months and, depending on the

weather, a fair amount during midsummer. If a considerable acreage of such land is available (a situation rare in Massachusetts) and some form of supplementary grazing is available during midsummer, permanent pastures may supply most of the grazing requirements. An extensive system such as this can be used to particular advantage with beef cattle, dry stock, young stock, and sheep, or with dairy cattle on medium production. On most farms, it is desirable to maintain a number of small permanent pasture lots conveniently located near the buildings to be used as overnight pasture or for some other reason in which accessibility is important.

It is obvious that there are in Massachusetts large acreages of permanent pastures, much of which should and probably will shortly revert to forest.

Semi-Permanent Pastures

Adequately fertilized, well-managed, semi-permanent pastures have great potentialities. Not only will such pastures go far in solving the pasture problem in Massachusetts but, in addition, they will aid greatly in solving problems relating to soil fertility and soil conservation. Where land acreage is limited and grazing requirements heavy, the normal condition throughout most of the State, a source of grazing must be sought which is more productive and more dependable than the permanent pasture. Semi-permanent pastures are already extensively used and the acreage is rapidly increasing. One of the principal reasons why farmers have not used this type of pasture to a still greater extent is that many of them do not even yet fully appreciate many of its actual and potential advantages

Perhaps the most important advantage of the semi-permanent pasture is that once every few years the farmer has an opportunity to deal directly with that all-important problem of soil fertility. When he plows to seed or reseed a field, he can apply adequate amounts of suitable fertilizer as well as barnyard manure and he can mix these materials thoroughly through the plow layer of soil where they will most effectively promote the growth of the new seeding. Plowing makes possible the decomposition of the old sod or any other kind of raw organic matter which may have been turned under so that, where mineral deficiencies have been satisfied, the many benefits which accrue from decomposing organic matter in the soil may be realized. The semi-permanent pasture presents an opportunity to deal directly with the pasture soil fertility problem easily and effectively. Stapledon has recently written, "If only all interests concerned will properly evaluate the meaning and far-reaching implications of the golden word *fertility*, then great things will indeed happen."[144]

The semi-permanent pasture gives the farmer an opportunity to control, for a few years at least, the kind of plant he grows in his pastures. He can seed pasture strains of species which will deliver not only much greater total herbage yields, but yields which are well sustained throughout the grazing season despite the vagaries of the weather. He is able to select plants particularly well adapted to certain kinds of livestock or a particular type of soil or to suit any personal preferences. It is only the semi-permanent pasture which will benefit greatly from the present extensive program of plant breeding which is being carried on all over the world.

A third important attribute of the semi-permanent pasture is its great flexibility. Many of the seeding mixtures can be used for hay, for grass silage, or for pasture. This gives the farmer a splendid opportunity to insure his grazing re-

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[144]Plough-Up Policy and Ley Farming, p. 170.

quirements against the unfavorable effects of the weather. In favorable seasons the surplus crop can be made into hay or grass silage. In unfavorable seasons any surpluses which existed at earlier periods can be used to fill later feed requirements. By using strains and species of varying seasonal maturities in different fields, he can spread his haying or grass silage operations over a longer period of time and in doing so he can make more effective use of his rowen or aftermath grazing. It must be conceded that the semi-permanent pasture magnifies the grazing management problem, but the benefits to be derived from a well-co-ordinated, properly controlled system of grazing far outweigh the few disadvantages which exist.

The last important potentiality of the seeded or rotation pasture is the logical role it should play in a well-conceived system of "grassland agriculture." In the writer's opinion, a grassland system of agriculture for Massachusetts does not imply decreasing the acreage of tilled crops and increasing the acreage in grass, nor does it mean keeping to the present long-continued practice of growing tilled crops continuously on certain restricted parts of the farm and grass continuously on other parts. A logical system of grassland farming will alternate insofar as practical the tilled crop with the sod crop, a system which will operate to the mutual advantage of both crops. More than a hundred years ago S. F. Dickinson said of farming in Massachusetts, "Alternate ploughing and seeding is a valuable substitute for manure; and an economical method of keeping land in heart.'[145] Stapledon has more recently written, "The ley itself is the pivotal crop in any good system of alternate husbandry, both for the feed it produces and for the sod it develops. Both feed and sod properly disposed of carry fertility around the whole farm."[146]

The difficulties which have frequently been enountered in Massachusetts in the use of sod crops in rotations probably resulted from inadequate fertilizing of the land while it was in sod. When the hay or pasture crop is permitted to exhaust most of the available soil fertility, an operation at which grass is very efficient, the succeeding crop, particulary if it is one with high fertility requirements, will usually make poor and unsatisfactory growth.

The grass crop is one of infinite usefulness and one which can be made to serve a wide variety of purposes; but its success, together with the success of crops grown in rotation with it, centers around the key words *soil fertility.*

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[145] Address to the Hampshire, Franklin and Hampden County Agricultural Society (Amherst, 1831), p. 10.

[146] Plough-Up Policy and Ley Farming, p. 150.

MASSACHUSETTS
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Spraying to Control Preharvest Drop of Apples

By Lawrence Southwick and J. K. Shaw

The use of "hormone sprays" to reduce preharvest drop is a new development. This bulletin reports results of recently conducted tests in an attempt to evaluate the method, especially in relation to McIntosh.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

These photographs show the marked difference in the amount of drop in one 24-hour period, September 2–3, 1940, between sprayed and check Duchess trees. The tree in the upper picture received a hormone spray on August 28. The response was outstanding and was unequaled in tests with other varieties. (See Table 1 and text.)

SPRAYING TO CONTROL PREHARVEST DROP OF APPLES ESPECIALLY IN RELATION TO McINTOSH

By Lawrence Southwick, Research Assistant in Pomology
and J. K. Shaw, Research Professor of Pomology

INTRODUCTION

The dropping of fruit just before and during harvest often causes considerable loss to apple growers. In Massachusetts the problem centers around McIntosh, the leading commercial variety and a notoriously "bad dropper." However, this fault is not limited to any one variety. It is natural for any apple upon approaching or attaining maturity to terminate its intimate connection with the tree and fall to the ground. Nature's purpose has been accomplished in the production of mature seeds to perpetuate the species. But unlike nature, man is concerned primarily with the flesh of the apple which, unfortunately, is particularly susceptible to physical injury and deterioration. In short, apples belong to the class of very perishable "handle with care" farm products and many precautions are necessary to prevent bruising. One of the first requisites is to harvest apples before they drop to the ground. On the other hand, apples should be allowed to mature properly in order to develop size, color, and quality. With some varieties, this development is not as satisfactory at the time dropping begins as with some others. McIntosh is a good example. Because of its recognized tendency to drop before full development, many McIntosh are harvested early and thus deprived of the chance to develop that exquisite quality that should be associated with this variety. This is especially true with the larger orchards where, in order to finish the harvest before disastrous dropping takes place, an extra early start is a practical necessity. A further impetus to early picking is the insistent demand for McIntosh at that time. Buyers urge growers to "color pick" in order that this demand may be supplied. Too often this demand is over-supplied with immature, poor-quality fruit. Consumers, fooled once, do not reorder and demand slackens. This depresses prices, which often show a decided tendency to resist a later, usually justified upward trend. In short, low-quality offerings at any time may limit the immediate sales, lower current prices, and even depress the price level for later offerings of better quality. Any development which promises to aid materially in getting apples to the consumer in prime condition is a step in the right direction. The proper use of the recently developed hormone sprays may help.

Development of Quality

The ultimate quality which an apple can develop depends to a considerable degree on its stage of development at the moment it is harvested. Following its removal from the tree, which has furnished its entire nourishment, an apple continues to respire and in so doing proceeds to use up its own energy resources. A stage called the "climacteric" is eventually

reached, by which time an apple has developed "good eating condition." That ultimate eating quality is due in large part to initial quality at time of picking is a logical conclusion. This is apparent in the generally accepted notion that McIntosh apples which have matured fairly well on the tree develop the highest eating quality. "Green" McIntosh, on the contrary, never do reach this state. The idea that apples improve in cold storage is basically false. Low temperatures simply prolong the interval of ripening. Of course, no increase in red color occurs in storage. Studies at this Station and elsewhere indicate that delayed picking of McIntosh is imperative if the highest quality development is desired. Further, the studies show that early-picked "green" fruit often stores rather poorly. Color and quality in a crop from a given tree are often closely associated.

Use of Hormones

The use of hormone sprays to delay dropping of McIntosh just prior to and during harvest, if sufficiently successful, should encourage growers to delay picking somewhat in order to take advantage of this critical period in quality and color development. Improvement of an entire crop in these factors would be a significant accomplishment, especially if it were not accompanied by disproportionate losses due to excessive dropping. Further, it has been shown in a previous publication (6) that McIntosh apples continue to grow in size into October and that a very significant increase in yield results from this late-season growth. It is the purpose of this bulletin to analyze briefly the results of some drop control experiments at the Massachusetts Experiment Station in 1940 and to evaluate the method in the light of the considerations just discussed.

EXPERIMENTAL TESTS

The work involved several tests with four varieties. Each test included two or three to many comparisons. Five commercial proprietary products and the pure naphthalene acetic acid powder were used. When the pure chemical was used, it was dissolved in a small quantity of alcohol and was then added directly to the water in the spray tank. Its low rate of solubility in water made this procedure necessary. The commercial products, being specially prepared to take care of this solubility problem, were used as received. When the manufacturers' directions were followed, assuming that their statements were correct, spray mixtures contained 10 parts of pure hormone to a million parts of water (10 p.p.m.) or 3.8 grams in 100 gallons. This was the "standard" or 0.001 percent concentration for 1940. The most effective chemicals (hormones) for harvest drop control seem to be naphthalene acetic acid and naphthalene acetamide. These two have been about equally effective in many tests. In commercial preparations, various hormone carriers, both liquid and dry, were used. A carrier dilutes the pure hormone and the resulting mixture is more readily handled and used by growers.

While most of the tests were made in the Experiment Station orchards, several cooperative tests with growers were followed rather closely. In practically all of the tests, the sprays were applied very thoroughly with a four- or six-nozzle broom at about 350 pounds of pressure. The attempt

was made to "wet" each apple stem. To do this, it was necessary to use from 15 to 40 gallons of spray per tree depending on the size of the tree and crop and somewhat on the density of the foliage. A small amount of summer oil (1 pint to 100 gallons) was included as a spreader in a few of the spray applications. No unforseen difficulties developed in actual spraying operations. A few growers have reported trouble due to excess foaming of some commercial hormone preparations. One grower reported some wear of leather gaskets, but it was not possible to trace this to the spray material. In case of any such injury, the fault would lie with the carrier. The active hormone itself would not be deleterious.

Effective Period of Hormone Sprays

The influence of hormones on the dropping of fruit is not manifest immediately following application. An interval of from 1 to 5 days elapses before any effect becomes evident or measurable. In these tests, the interval was usually 2 or 3 days, thus making the effect of the hormone on rate of drop discernible on the third or fourth day after spraying. It should not be assumed on the basis of this statement that dropping decreased suddenly and markedly at any particular time. In all the tests with McIntosh and Wealthy, the lessening of dropping usually was not apparent in the field to the casual observer, especially where treatments were randomized. This was due not only to variations in apparent effectiveness between trees within treatments, but often to the considerable differences in total yield among the trees. With Duchess of Oldenburg and an unnamed variety maturing in late summer, the effects were readily apparent and hardly needed yield and drop figures for confirmation. Table 1 illustrates a case of very effective control from the application on August 20 of a commercial hormone spray containing 10 p.p.m. of hormone and used at the rate of about 15 gallons of spray per tree.

TABLE 1.—DROPPING OF DUCHESS OF OLDENBURG
Average numbers of dropped apples per tree picked up during the ripening period. Test 8.

	Aug. 21	22	23	24	26	27	29	31	Sept. 2	3	Average No. of apples per tree
Sprayed	52.7	18.3	6.7	1.8	2.0	2.7	1.8	3.5	12.0	3.0	1095
Check	74.8	19.0	26.0	19.6	31.8	19.0	48.4	80.0	230.0	225.0	1198

Total drops per tree from August 23 to September 3 amounted to approximately one peck for the sprayed trees and over 5 bushels for the checks. Many of the apples were over-mature when picked on September 3.

Other fall varieties such as Williams, Melba, and Early McIntosh are reported to react similarly to hormone spraying.

After the effect is initiated, the length of time that it will be maintained depends greatly on the variety. As far as Duchess was concerned, the apples held on even after internal breakdown had commenced. Table 2

sums up the data of test 3 with McIntosh. The orchard used for this test consists of seven plots under different cultural and fertilizer treatments. Therefore, the drop control experiment was arranged so that the five spray treatments ran across the plots. These treatments in test 3 will be referred to as (a), (b), (c), (d), and (e).

Table 2.—Average Cumulative Percent Drop of Original Crop.
Test 3, McIntosh.

Test	Hormone Concentration p.p.m.	Spraying Dates	Cumulative Percent Drop Sept. 11	18	24	30	Oct. 5	Percentage Equivalent to a Bushel*	Average Number of Apples per Tree
3 (a)	10	Sept. 12 & 17	2.6	4.2	7.2	11.5	35.4	6.5	2154
3 (b)	10	Sept. 12 & 28	2.3	3.7	6.9	11.8	29.3	8.1	1736
3 (c)	5	Sept. 12 & 17	2.2	4.1	6.2	12.5	41.3	8.6	1621
3 (d)	5	Sept. 12 & 28	2.0	3.2	6.6	14.5	42.6	12.0	1170
3 (e)	Check		2.8	4.7	15.2	37.5	65.9	8.4	1670

*These percentages of the total crop equal one bushel of apples in each case.

The first spray was applied on September 12. One-sixth to one-third bushel of drops per tree had been picked up September 11. Many of these fruits were imperfect in one way or another and the fact that they had fallen was not a reliable indication that normal preharvest dropping had begun. This was proved to be the case since dropping from the check trees was light during the following week. Hence, this spray was applied too early. Nevertheless, as shown in Table 2, treatments (b) and (d), it did exert a beneficial effect in lessening drop over a rather long period. The influence of this spray was manifest at least to September 30—a period of 18 days from the time of application or about 14 days from the expected initial effective date. Most of the tests indicate that in general the effect of hormone sprays on McIntosh may be expected to last around 10 days. In one test the dropping increased noticeably on the eighth day after the effect first became evident. When the fruit was harvested before the effect of the hormone had worn off appreciably (usually within 12 days from date of application), the numbers of apples that dropped during the picking operations were considerably less with the sprayed trees. This was seldom true when picking was delayed too long.

Similar results in other states have been reported in regard to the length of the effective period with McIntosh. Batjer and Marth (1) in Maryland concluded that the maximum effective period of a spray extends generally 10 to 12 days from the application date. Murphy (5) in Rhode Island and Hoffman (3) in New York drew similar conclusions. Other reports are corroborative.

The effective period on other varieties seems to vary considerably. This year's experience with Wealthy indicates that it behaves similarly to McIntosh in this respect. With some later-maturing varieties, the evidence indicates a more prolonged period of effectiveness. This was found to be true, for example, with Delicious and Stayman Winesap (1).

When to Apply a Hormone Spray: Repeat Sprays

It was stated that in test 3 (table 2) the September 12 spray application was too early. The data show that this spray might have been delayed somewhat without undue risk. Since the effective period of a hormone spray on McIntosh is definitely limited, it is to the grower's advantage to delay as long as possible before putting it on. The endeavor to determine the proper time showed that there are many considerations which may upset any hard and fast rule. It must be remembered that when the retarding effect of the hormone wears off, dropping may be sudden and severe. This evidently happened after October 1 with McIntosh in the tests reported in Table 2. Despite the second application on September 28, heavy dropping resulted. In fact, the increase in dropping was relatively larger with the sprayed trees than with the checks. A repeat application on October 2 on a few trees in one of the tests had a slight influence but was unsuccessful in materially slowing up the severe rate of dropping. The failure of repeat sprays with McIntosh is also reported by Batjer and Marth (1) who offer the explanation that when abscission has progressed beyond a certain stage spray applications of hormones will not retard the process.

With some varieties, a repeat spray closely following the initial spray increases effectiveness of drop control (2). This probably is due to a "building up" of protection or to a more complete coverage. However, with McIntosh in 1940 repeat sprays did not prove particularly advantageous. In Table 2, it is difficult to see any added beneficial effect of the September 17 application (treatments (a) and (c)). The accumulated drop to September 30 for the trees receiving this application was just about equal to the drop of the trees which had had only the September 12 spray (treatments (b) and (d)). The application on the 28th, of course, had not become effective. In another test with 10 large trees per treatment, results were as follows:

2 sprays (10 p.p.m.)	3.1 percent drop
1 spray (10 p.p.m.)	4.4 percent drop
Check	19.9 percent drop

Here, the repeat spray, 6 days after the first one, did have a beneficial effect, but it was of minor importance. However, in Rhode Island (5), a second application 6 days after the first seemed to increase by 4 days the period of effectiveness. Batjer and Marth (1) found that a repeat application (in 7 days) increased the effective period only 1 to 1½ days longer than the single application treatment. They found little added benefit from any sprays following the initial application. Additional data on this point may be needed, but the evidence at hand seems to show that repeat applications, at least with McIntosh, are hardly warranted.

It is evident then, that with McIntosh it is doubly important to determine the best time for hormone spray applications. On the basis of the evidence to date, it would seem advisable to wait until the preharvest drop has begun and then to apply one spray only. The dropping of injured or wormy apples at this season should not be used as a certain indication that preharvest dropping has definitely commenced. When average-sized, well-shaped, sound, clean apples have begun to drop in any quantity—20 to 25

to a large tree—then a spray should be applied immediately provided the crop can and will be harvested within about 12 days. With some other varieties a spray application may precede the harvest date by considerably longer periods than is the case with McIntosh. For instance, the effect with Winesap has persisted longer than 4 weeks from the date of spraying. However, with all varieties there is a time limit beyond which effectiveness decreases markedly. With McIntosh and Wealthy this interval seems to be peculiarly short.

Effect of a Single Late Application

It is possible, of course, to apply hormone sprays at any time after dropping has begun. Common sense, however, imposes certain limits. For instance, since the effect from an application will not be manifest for from 2 to 4 days, there obviously would be little justification for spraying trees which are to be picked within 4 or 5 days. Furthermore, as the proportion of a crop which has dropped increases, the probability of an economical use of hormone sprays decreases. Finally, a point is reached where an application is not justified.

It has been stated that a spray should go on very soon after dropping has commenced in some volume. But suppose that a grower, for some reason or other, fails to pick or to spray a block until one day he observes that perhaps one-third of the crop is on the ground? Furthermore, he figures that he will not be able to pick the block for another week. Will hormone sprays be helpful? This question cannot be answered categorically because no two situations are strictly comparable. Table 3 illustrates what happened in one such case in an experimental block at Massachusetts State College.

TABLE 3.—AVERAGE CUMULATIVE PERCENT DROP OF ORIGINAL CROP.
(Sprayed September 28—Harvested October 7)

Test	Hormone Concentration p.p.m.	Cumulative Percent Drop Sept. 26	30	Oct. 1	2	3	4	5	7	Average Number of Apples Per Tree	Calculated Bushels per Acre Dropping After Oct. 1
4 (a)	10	19.0	34.4	39.8	42.2	45.2	47.6	49.8	56.0	1189	75
	Check	20.8	32.9	38.5	43.0	47.7	54.9	61.0	74.2	819	115
											40
4 (b)	10	30.0	39.1	44.1	46.7	48.8	49.9	51.4	58.6	1726	50
	Check	30.6	37.8	43.6	46.8	51.4	57.4	62.8	74.4	1520	105
											55

This test (Number 4) is separated into two parts: (a) young trees, (b) mature trees. It is interesting to note the similarity of results. The spray, which included one pint of oil per 100 gallons, was applied on September 28. The effect is barely discernible in the table on October 2 and becomes progressively more pronounced up to the time of harvest. It

should be noted that the average dropping percentages of the sprayed and the check trees in each case were practically equivalent up to October 2. Although the actual yields are not the same, estimates of the drops per acre based on these yields are given. Under conditions of these tests, a saving of about 50 bushels per acre could be attributed to the late hormone spraying. These estimates are based on 27 trees to the acre for the large trees and 50 trees to the acre for the smaller ones. Of course this arbitrary analysis is for comparative purposes only. No two tests could be expected to give identical net results. Thus, if the above yields had been higher, the benefit from spraying would have been enhanced.

Two other tests were conducted where spraying was delayed even longer than in the above cases. There was some effect from these applications, but the results probably did not justify the cash outlay and the time expended. Furthermore, the data indicate that the effectiveness of a hormone spray application on McIntosh may be progressively less pronounced as the crop becomes more and more mature on the tree. Involved, of course, is the question of decreasing temperature means as the season progresses. Late spraying of York Imperial and Rome Beauty in Maryland (1), Baldwin in Rhode Island (5), and Baldwin at Amherst was generally unsuccessful in lessening subsequent dropping. This possibly may be explained on the basis of the low physiological activity of the tissues of the tree late in the fall. Without ignoring the question of variety itself, the above argument is supported by the fact that early apples usually are more likely to react favorably to hormone applications than late varieties.

It is a widely accepted fact that losses from preharvest dropping of McIntosh were, in general, less pronounced in 1940 than in many previous years. This was certainly true in Massachusetts. As a result, several investigators have concluded that the response of McIntosh to hormone sprays in 1940 may not represent a true index of response for a normal season. August and September were relatively cold months, the Amherst mean temperatures being respectively 1.7° F. and 1.6° F. below normal. That the effectiveness of the hormone in a spray is influenced greatly by differences in temperatures at a critical time has not been proved, but may offer one explanation for certain differential results. It has been observed that high temperatures at this season increase preharvest dropping of apples. This is discussed at greater length in a previous publication (6). It is sufficient here to emphasize the important influences which temperature may have on drop. With high temperatures, which favor dropping, the usefulness of hormone sprays may be enhanced.

Effect of Concentration

The amount of active hormone in the spray solution seems to be very important. The proprietary commercial hormone preparations on the market last season were designed to furnish 10 parts of hormone per million parts of water when the manufacturer's recommendations were followed. This is a .001 percent concentration. Table 4 summarizes results secured as a result of reducing the hormone concentration. Three commercial preparations were used. In every case, some decrease in effectiveness resulted from the use of the lower hormone concentrations.

This finding is substantiated, in general, by results elsewhere. Gardner,

Marth, and Batjer (2) in their first full report in 1939 stated that with McIntosh ". . . . as with other varieties, the higher concentrations have given better control within the effective period." Some further work (1940) by Batjer and Marth (1) supports this statement, especially in regard to late varieties. However, with some varieties, particularly Williams Early Red (1) and McIntosh[1], drop control was not necessarily improved by increasing the hormone concentration above 5 p.p.m. Also, Murphy (5) in Rhode Island found no significant differences in the drop of McIntosh from trees receiving sprays with different hormone concentration. Considerable variability was evident within treatments. The results of Hoffman (3) in New York with McIntosh suggest that the standard .001 percent sprays were possibly a little more reliable than sprays with half the amount of hormone. Murneek (4) found more reduction in amount of dropping of Delicious with a .001 than with a .0005 percent spray. Other experiments seem to present a further picture of variability in results. However, the evidence on the whole seems to verify the authors' experience that the higher concentrations up to 10 p.p.m. are usually somewhat more effective in controlling preharvest drop. A test (McIntosh) in Canada[2] resulted in better control with about 15 p.p.m. of hormone than with the standard 10 p.p.m. spray. In a single test with Baldwin at Amherst, a similar high concentration seemed to increase effectiveness. But most of the sprays contained 10 p.p.m. or less of actual hormone. Table 4 gives some results with McIntosh and Wealthy.

TABLE 4.—PERCENTAGE OF TOTAL CROP THAT DROPPED AFTER TREATMENTS BECAME EFFECTIVE IN SEVERAL TESTS.

Test	Variety	Date Sprayed	Date Harvested	Hormone Concentration p.p.m.	Average Percent Drop	Average Number of Apples per Tree
1	McIntosh	Sept. 13	Oct. 2	10	12.3	1307
				5	14.0	715
				Check	15.7	670
2	McIntosh	Sept. 14	Oct. 2	10 (+ oil)	12.6	4024
				2½ (+ oil)	16.4	2382
				Check	24.3	1754
5	McIntosh	Sept. 13	Sept. 23	10	4.2	2562
				5	6.6	1976
				Check	19.3	3521
6	Wealthy	Sept. 4	Sept. 20	10	22.2	3801
				5	30.8	3852
				Check	36.8	2700
7	Wealthy	Sept. 4	Sept. 19	10	12.1	2153
				5	30.9	1065
				Check	29.6	1076

[1]L. P. Batjer. Correspondence. 1941.

[2]G. H. Dickson. Correspondence. 1940.

The data in Table 4 do not show uniformly good results from spray applications (note test 1) and few of the differences in percentages of drop due to hormone concentration are large enough to be significant. Whether any of the differences are sufficiently pronounced to justify the use of the stronger sprays is a matter of opinion. For example, let us briefly analyze test 2. The average tree yield of the block was 20.1 bushels. This average is used rather than the actual yields because of the large variations in the latter. Since higher percentages of drop often have been found to be associated with heavy production (6), the calculations herewith tend to be conservative. That is, the check trees rather than the treated trees are favored because the lower yielding trees (this particular season) were chosen for the check trees. Now, on the basis of 27 trees to the acre, the bushels dropped per treatment per acre were as follows: 10 p.p.m., 68.3; 2½ p.p.m., 89.8; check, 131.8. In short, the weak spray application saved 42 and the strong 63.5 bushels. The difference is 21.5 bushels of McIntosh apples per acre. The costs of application were the same except for the difference in the amount of hormone material used. Assuming a figure of 1.5 cents per gallon of spray as the actual cost of the hormone, this item of cost per acre based on 30 gallons per tree was $12.15 for the stronger spray and $3.04 for the weak spray, making a saving of $9.11 per acre in the case of the latter. The problem is resolved to the question of the economics of spending $9.11 to save 21.5 bushels—approximately 42 cents per bushel. This analysis considers the problem only in terms of the actual bushels of apples saved. There are other considerations which should not be ignored, however, such as the increased development of quality; the nature of the surface on which the drops would fall, which largely determines injury to and hence the salability of dropped McIntosh; and the local market situation in relation to disposal of such drops. A limited supply of good "drops"may find a ready market. Usually, the average market price for such apples, however, ranges from 50 cents to one dollar below that of hand-picked McIntosh out of cold storage.

Such an analysis could be made of each test in Table 4. In tests 1 and 5, the increased dollar value of the strong over the weaker sprays is much less pronounced than in test 2. With Wealthy (tests 6 and 7) the added effectiveness of the stronger sprays is evident and their use might seem justified on the basis of these tests. However, the varietal problem enters the picture here. For many Massachusetts growers it may never be profitable to spray Wealthy and some other "before McIntosh" sorts due to a characteristic downward trend in the price level for such varieties as the season progresses. Even with the very effective control of dropping that was obtained with Duchess, it is doubtful that hormone spraying can be economically justified with such a variety.

Thoroughness of Application

As with spraying for disease and insect control, hormone spraying for drop control is dependent for effectiveness upon good coverage. Best results have been obtained when sufficient spray was applied to "wet" the entire tree thoroughly. The most effective part of an application has seemed to be the spray that hits and wets the fruit stems. Theoretically,

for best control, the hormone should come in contact with the abscission zone itself. This is the area that roughly defines the location of the abscission layer which, upon development, separates the pedicel from the cluster base (the stem from the spur). Gardner, Marth, and Batjer (2) have reported some effect from a spray applied only to the calyx end of Delicious fruits. But such an effect must be of doubtful significance. They also found that leaf coverage is not particularly important. Apples only a short distance away from sprayed foliage seem to be affected little if at all.

The amount of spray material which is adequate for thorough coverage depends on a number of factors such as wind movement, spray pressure, and especially spraying technique. Material, of course, should be applied efficiently with a minimum of wastage, but it is better for best control of drop to apply too much than too little. Reports of amounts used in 1940 vary remarkably. In some cases, good results evidently were secured with young trees when less than 5 gallons of spray were used per tree. Another extreme was the application of more than 40 gallons on single trees. These, of course, were very large trees bearing 15 to 40 bushels of apples. Two ways of determining the amount of spray material needed are based respectively on tree size and on tree crop. Competent men on a spray rig will automatically consider both aspects. With hormone spraying it is the apple rather than the leaf that deserves primary consideration and this fact naturally places emphasis on the crop of fruit rather than on the size of tree. On this basis, a recommended application might be from one to two gallons of spray for each estimated bushel of apples. Results have been too inconsistent and individual situations are too variable to allow a more specific recommendation. The important point is that very thorough coverage is essential. For example, in Maryland (1), with Delicious averaging seven bushels per tree, a 5-gallon application per tree was just one-half as effective in retarding drop as a 10-gallon application of the same strength.

This brings up the possible use of dust in a drop control program. Several advantages of dusting over spraying are obvious to those who have used both systems. One of the most important considerations is the shorter time required for dusting. Since hormone spraying comes during a particularly busy season, the time required to put on an application is of vital concern to growers. Hence, the question of incorporating the hormone in a dust carrier for use in the usual orchard dusters has been raised. Although the efficacy of this method of hormone application to fruit trees is practically unknown, it is believed that dusting will not effect as thorough coverage as spraying. Intimate contact with tissue surface is better obtained with a wet than with a dry film of material. The question is further complicated by the fact that, to be most effective, the hormone probably should be in solution, although for certain other uses dust application of hormones has been quite effective. The possibilities of hormone dusts are being investigated further and it is possible that certain of the obvious difficulties may be remedied. At the moment, however, since spraying itself is none too effective, partly because of inadequate coverage, a dust program for drop control offers little encouragement, especially with McIntosh.

Addition of Oil

In 1939, Gardner, Marth, and Batjer (2) reported increased effectiveness of drop control sprays when a small amount of oil was added. Since it seemed that even a small quantity of oil might act as a spreader and improve coverage, it was included in some tests with McIntosh. The addition of a summer oil (1 pint per 100 gallons) had an effect similar to that reported above. For example in one test, using 10 p.p.m. of hormone, the dropping amounted to 10.2 and 14.1 percent respectively with and without oil. The check trees dropped 24.3 percent. Further work may indicate that the use of oil may compensate in part for decreased hormone concentrations. At the present time, however, it should be considered as a supplementary procedure to enhance the action of the hormones. Its use should not affect apples in appearance, quality, or storage ability.

Importance of Size of Crop

It has already been suggested that the amount of fruit on a tree may be a deciding factor in determining the advisability of using a hormone spray to lessen dropping. The grower is interested in actual bushels, not in mere percentages. Percentage figures in themselves, as related to dropped apples, mean little in terms of monetary gains or losses. However, when a grower reads that a hormone spray has reduced drop by 10 percent, he immediately associates this percentage figure with an arbitrary orchard or acre yield, or possibly with the known performance of his own trees. The "10 percent" then becomes "bushels per tree" or "bushels per acre" and has a definite meaning so far as that grower is concerned. Other growers will interpret differently as a result of different yield standards. Thus, with a 200-bushel yield per acre, a reduction in drop from 15 to 5 percent means a saving of 20 bushels. Such a reduction with a 600-bushel yield, on the other hand, gives a saving of 60 bushels per acre—an increased saving of 40 bushels. Hence, it is evident that size of crop is especially significant in the economical use of hormone sprays. The heavier the yield, the more justification there is for a hormone application.

Orchard Variability

Since the purchase of hormones and their application cost considerable money, it is wise for each grower to consider carefully to what extent this method of decreasing drop should be utilized under his particular conditions. No two McIntosh orchards are alike. Even similar appearing orchards in close proximity often behave differently in regard to preharvest dropping of fruit. This same variability may exist among neighboring trees in a single block. It has been shown also that severity of drop with McIntosh may be associated with a high state of fertility, especially in relation to nitrogen. These relationships have been discussed fully in a previous publication (6). Briefly, when available nitrogen is plentiful and trees are in a vigorous state of growth, more severe preharvest dropping of apples is likely to occur than when trees are grown on the "hard side." Since good vigor is essential for high production, a method to reduce premature dropping other than by decreasing vigor is of paramount significance. The use of drop-control sprays is especially

adapted to such a setup. Past records of drop should enable growers to choose the particular orchards that have caused the most trouble with excessive fruit drop year in and year out. These should have precedence in receiving hormone sprays over orchards which have a record of producing fruit that attains good size, color, and maturity before falling to the ground.

Experiment with Excised Branches

Two similar branches of a McIntosh tree were chosen for a comparative study of fruit drop following their removal from the tree. One was sprayed thoroughly on September 18 with a hand pressure sprayer using a spray containing 20 p.p.m. of naphthalene acetic acid. The other branch served as a check. On September 22 the two branches were carefully removed from the tree and the cut ends were placed in water. The branches were supported so that their previous positions relative to the horizontal were approximately maintained. There was some dropping of apples within a few days from the unsprayed branch, and apples continued to absciss until all (23) had dropped. The hormone-treated branch, however, showed practically no dropping of its 36 apples for longer than two weeks. Even a month later, after two freezes, some apples were still hanging. Previous work (6) has indicated that an injured limb may exhibit delayed dropping of fruit to some degree and possibly these branches so behaved. However, the effect from the spraying was far more significant than the effect from the cutting itself.

SUMMARY AND CONCLUSIONS

The use of so-called hormone or drop-control sprays to decrease the preharvest dropping of apples offers some promise to fruit growers in Massachusetts. The method is still in the development state and the material in this bulletin sums up much of the present knowledge concerning it. Some aspects are more definitely established than others where results have not been sufficiently extensive or uniform for positive conclusions. That certain chemicals, such as naphthalene acetic acid and naphthalene acetamide, when dissolved and diluted in water and applied to apple trees around harvest time, exert a retarding effect on natural fruit drop is well authenticated.

There is no doubt also that the effect of these and other chemicals is variable. Many factors may contribute to this variability, such as variety, time of application, thoroughness of application, concentration, weather conditions, and season. These factors and other considerations have been discussed and the attempt has been made to evaluate their significance on the basis of experimental tests. Most of the work was done with McIntosh.

The effective period of hormone sprays is the number of days that a retarding influence on drop is maintained and varies greatly with variety. With McIntosh and Wealthy this period was about 10 to 12 days. With other varieties, it is usually somewhat longer.

The practical effect of a spray application is not immediately apparent. Usually from two to three days elapse before dropping is measurably

retarded. The interval between application and effect may be longer if the temperature is relatively cool.

The response of different varieties is variable. Drop control was most successful with Duchess of Oldenburg and an unknown early fall variety, and least successful with Baldwin. Control was variable with McIntosh and Wealthy. Reports from tests in other states show that early varieties in general responded better to hormone sprays than later varieties, although there were exceptions.

The application of hormone sprays must be timed accurately for best results, especially with McIntosh. As soon as well-sized and uninjured uniform apples begin to drop in any quantity, a spray should be applied.

Most repeat sprays were unsatisfactory. A single application, well timed, should furnish the most economical protection.

The longer an application is delayed after dropping has commenced, the less opportunity there is for benefit from a commercial standpoint.

The concentration of hormone in the spray had a decided influence on the degree of drop control. Better results were secured as the amounts of chemical were increased up to 10 parts per million of water. Whether increased effectiveness warrants the extra cost for material is not definite. At the moment it seems unwise to use the lower concentrations with McIntosh. Whether higher concentrations than 10 p.p.m. might be justified has not yet been shown.

It is essential to wet each apple stem for best control of preharvest drop. This means very thorough coverage—10 to 40 gallons per tree or 1 to 2 gallons per bushel of fruit. Dusting does not seem feasible at the present time.

The inclusion of a small amount of summer oil tended to increase effectiveness. One pint in 100 gallons of spray did not seem to affect the fruit in any way.

The temperature before and during the normal harvest season may be very important. Warm weather seems to have an accelerating effect on fruit abscission. Cool weather delays fruit drop. It is possible that hormone spraying is more effective in warm weather.

There is no evidence that would indicate any harmful effects from the proper use of hormone sprays on the fruit, on the tree, or on consumers.

It is probably to the growers' advantage to use the commercial preparations. There is not sufficient evidence at the present time to permit the recommendation of one commercial product more than another.

In Massachusetts any extensive use of hormone sprays will be limited largely to McIntosh and possibly one or two other varieties in particular cases. There is often a good but limited market for drop apples, especially McIntosh, and a small grower may have no difficulty in moving this part of his crop. The advantage of hormone spraying in such instances will not be sufficient to warrant its use.

Harvest sprays with McIntosh seem likely to be most profitable—

1. In orchards that have a record of dropping badly in previous years.
2. In orchards that usually produce poorly colored fruit.
3. In orchards that are in vigorous growth from natural fertility, heavy mulching, or liberal fertilizer application.
4. In orchards where the crop is good to heavy.
5. In orchards where harvesting is delayed.

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The Propagation of Some Trees and Shrubs by Cuttings

By William L. Doran

The detailed information regarding recent developments in plant propagation dealt with in this bulletin should be of significant economic importance, especially to nurserymen and foresters.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE PROPAGATION OF SOME TREES AND SHRUBS BY CUTTINGS

By William L. Doran, Research Professor of Botany

Research on the propagation of trees and shrubs by cuttings, a subject of particular interest to nurserymen and, increasingly, to foresters, has been stimulated in recent years by the coming into use of certain root-inducing substances and considerably more has been learned than merely how to use such substances. Much remains to be learned but, for the convenience of propagators and other investigators, some of the results are now brought together.

Work done here and described below has involved the rooting of cuttings of 122 species, some of them represented by a number of varieties and hardly two of them exactly alike as regards requirements for best rooting. Some of the more noteworthy of these species, either because cuttings have been considered especially difficult or slow to root or because there has been so little information about their propagation by cuttings, include white cedar, red cedar, incense cedar, white pine, Pfitzer juniper, Asiatic sweetleaf, Japan quince, American elm, and species of Magnolia, Corylopsis, Hamamelis, Fothergilla, Poncirus, Helwingia, Stewartia and Idesia.

No brief and general conclusion, other than that different species respond differently, is now attempted, for factors which affect rooting include the species (or even variety) itself, the type or condition and time of taking of cuttings, concentrations and methods of applying root-inducing substances if any are used, the rooting medium, and environmental conditions (temperature, light and moisture) during rooting. These and other factors are separately considered below, following which there is a list of species (names taken from Rehder (84)*) the cuttings of which have been rooted here or elsewhere by the methods mentioned in connection with each. Common names are used when there are any and an index is appended.

It is not to be assumed that all species named are best propagated by cuttings rather than by other means—seeds, grafting or layering for example. But if cuttings are used, and if they are taken and handled or treated as described, results to be expected should be about as indicated.

Unless stated to the contrary, cuttings were rooted in greenhouses or under glass and were not treated. Treatments, as will be seen, are not always worth while. Cuttings designated as "treated" were treated with a root-inducing substance, indolebutyric acid unless otherwise indicated. Time of taking cuttings and treatments described are those which gave the best results or, in some cases, the only ones tried. The emphasis is, in general, on methods which were successful or relatively successful rather than on those which were not.

Cuttings which are described as rooting better, rooted in larger percentages than did the cuttings with which they were being compared. In referring to work done here, percentages recorded, unless otherwise

*Numbers in parentheses refer to Literature Cited. See page 41.

stated, are those which had rooted when all unrooted cuttings had died. Some investigators, in reporting upon their work, have not made that point clear and one can conclude no more than that a certain treatment or method of handling did or did not hasten rooting; a difference important with some species, not with others.

Most of the cuttings used here were taken in Amherst, either on the campus of Massachusetts State College or in the garden of the writer. Some of them came from the Arnold Arboretum in Boston and the kindness of Dr. E. D. Merrill, in permitting their collection there, is gratefully acknowledged. Amherst is about 90 miles west and inland from Boston but, being in the Connecticut Valley, it is probably less than that distance from the effect of sea on climate, and cuttings of a given species collected at or about the same time in these two towns did not respond very differently.

Time of Taking Cuttings

Time of taking cuttings or age of wood, which is almost but not quite the same thing, is an important factor. Softwood cuttings of some species root well if taken in late summer or after growth has stopped. Cuttings of others root better if taken in late spring or early summer while the wood is still growing. Cuttings of many species can be taken with fair success during a period of several weeks or months. For others, the time limits are narrower, the best time varying somewhat with locality, weather of the season, or from year to year. Cuttings of mayflower root better if the summer has not been very dry (6). Lilac cuttings taken in mid-May one year were equivalent to those taken two weeks earlier the year previously (49). Climatic differences between years may affect response to treatments (18). Cherry cuttings taken at about the end of June responded to a certain treatment one year, not the next (12). The amount of light preceding the taking of cuttings influences their response and it is possible that cuttings taken during a long period of sunny weather are benefited by a lower concentration of a root-inducing substance (17). Starch content fluctuates but that did not, in the case of hardwood cuttings of rose, have much effect on rooting (10).

Occasional reference is made to seasons at which cuttings are taken in England but it does not follow that they are to be taken here at exactly the same times. There is, however, no great difference in the case of certain species. It is English practice to take cuttings of lilac in June, and of Deutzia, Lonicera, Philadelphus, Itea and Viburnum in July; and these are good months in which to take softwood cuttings of those shrubs here.

Many deciduous species can be propagated by hardwood cuttings taken during dormancy in late fall, winter, or early spring. These are either planted at once in a greenhouse or, more commonly, stored in moist sand or peat in a cool place until spring when they are set in the field. For such plants as can be thus propagated, this is the simplest method. Among the woody plants which can be propagated in this way are buckthorns, firethorns, currants, sumacs, alders, grapes, wistarias, buttonbush, trumpet-vine, ninebark, Virginia creeper, bladdernut, tamarisk, Chaenomeles, Elaeagnus, Akebia, Catalpa, Euonymus (32) and a number of others, some of which are mentioned below.

Differences Between Individual Plants

Age of tree from which cuttings are taken, regardless of age of wood of which cuttings are made, is also a factor. Cuttings of some species, including dove-tree (64), hemlock, white pine (24), apple, pear, Catalpa, white elm, black locust, cherry plum, Mahaleb cherry (33), Norway spruce, Ginkgo, Norway maple, red oak, and white ash (109) root more freely if taken from young, seedling trees than if taken from mature trees, and the ability of some of these to root well without treatment decreases rapidly as trees become more than one, two, three or four years old. It may be assumed, unless stated to the contrary, that the work described in this bulletin was done with cuttings from mature trees.

Cuttings from some individual trees root more or less readily than cuttings from some other trees of the same species even though all are of the same age. American holly (129), white pine, Norway spruce (24) and red maple are examples. Snow (93) took softwood cuttings of red maple from a number of different trees in early July, treated them with indolebutyric acid (200 mg. per liter for 6 hours) and planted them in sand–peat outdoors. Average percentages which rooted varied from about 97 to about 17 percent for different trees or clones, a clone being, as he uses the word, "a group of plants which have originated by vegetative propagation from one individual seedling."

Making Cuttings

Unless indicated to the contrary, it may be assumed that cuttings are made of wood of the current year, wood not more than one year old. There are a few exceptions, including *Chimaphila umbellata,* July cuttings of which rooted better if made of wood two years old (69); pecan (hardwood cuttings) (95); and many conifers, cuttings of which root well if so made as to include all of either one or two years' growth (61). The larger the conifer cutting, the larger the root system is likely to be (123) and a rooted large cutting is, of course, more of a plant than a rooted small cutting. A good way to make cuttings of some conifers is to make them of complete shoots, cut or pulled from the plant at a yearly ring. "Heeled" cuttings, cuttings with a bit more of heel or older wood at the base can, in the case of many species, be made by pulling rather than cutting the cuttings from the plant.

In the work of Chadwick (14) with softwood cuttings of deciduous plants made to include part but not all of the current year's growth, the best place for the basal cut proved to be about a half inch below a node in the case of 75 percent of the species; at a node in the case of sweet pepperbush, golden-chain, madenhair-tree, box, pea-tree, beauty-bush, alder, buckthorn, *Photinia villosa, Potentilla fruticosa* var. *Veitchii, Viburnum Sieboldii, Pyracantha coccinea* var. *Lalandii,* and six species of *Cotoneaster;* and about a half inch above a node in the case of California privet, common privet, *Magnolia stellata,* and *Weigela florida.*

The more leaves there are left on leafy cuttings of most species, the better they are likely to root, provided, always, that wilting or most wilting is prevented. Basal leaves are usually removed to make it easier to treat or insert cuttings in rooting media, and large leaves may be reduced in size or number; otherwise, leaf areas are usually kept at a maximum. There are a few exceptions mentioned below in connection with the species.

The making of leaf-bud cuttings, mentioned in connection with a few species, is briefly described in the discussion of Rhododendron.

Effects of Treatments with Root-Inducing Substances

Treatment of cuttings with a root-inducing substance such as indolebutyric acid is no substitute for care and skill in handling them; but the effects of treatment, with many although not all species, are to extend the season during which cuttings may be successfully taken (114) and to induce more rapid rooting, rooting in larger percentages, and early development of more roots per cutting. Cuttings with more roots do not always develop into better plants, however, than those which began with somewhat fewer (117); and if untreated cuttings root in good percentages, the propagator will have to decide for himself whether or not the saving of a few days or weeks in time required for rooting is important enough to warrant treatment (83). But if cuttings rooted by the aid of a root-inducing substance grow no better after rooting than do untreated cuttings, at least the treated cuttings usually grew no less well (62, 113, 125) and that is a point of some consequence.

The most common good effect of treatment with a root-inducing substance is to hasten rooting and it is perhaps by this very hastening that rooting is sometimes improved and percentages which root are increased. Cuttings which root more rapidly are, generally speaking, less likely to die unrooted, for the length of life of unrooted cuttings of most species is rather limited. They either root or rot. If they rot, it is partly because they did not root; but if they do not root, it is not necessarily and only because they rot.

It is unfortunately true that cuttings of species which root with great difficulty or not at all if untreated are the ones least likely to be much benefited and to root well if treated (57), the degree of response being more or less proportional to the ease with which untreated cuttings root (3). But the rooting of cuttings of many species is improved by treatment and as more is learned about the best time to take cuttings, the use and choice of root-inducing substances (there are now some fifty chemical compounds which are known to be growth-promoting (130)), and safe and effective concentrations for each species, the number which it is really difficult to propagate by cuttings will become less. There are at least 2550 species of trees and shrubs hardy in North America (84). Ascertaining the best treatment and method of handling for all of these or for those which are difficult to propagate by cuttings is slow work but it is proceeding and the number of species which can be readily propagated by cuttings will certainly increase.

Some Root-Inducing Substances Compared

Indolebutyric acid, alpha-naphthaleneacetic acid and indoleacetic acid, also their potassium salts (49), are highly effective root-inducing substances; and mixtures of indolebutyric acid and naphthaleneacetic acid are even more effective with cuttings of some species than is either substance alone (50).

Indolebutyric acid, as used here and by other investigators (12, 43, 48, 61, 83, 114), has given better results than indoleacetic acid with cuttings of most species. Among the exceptions are *Pyracantha coccinea, Lonicera*

Korolkowii (83) and mountain laurel (88), rooting of cuttings of which was more improved by indoleacetic acid.

Indolebutyric acid is also probably more effective than alpha-naphthaleneacetic acid for cuttings of most species (16, 25, 43, 48, 83, 114). Exceptions include oriental bittersweet (48), black locust (99), *Deutzia scabra* (34), *Lonicera nitida*, cherry plum (82), and species of privet (49) and yew (58), cuttings of which responded more to treatments with naphthaleneacetic acid.

Naphthaleneacetic acid is probably more effective with most species than indoleacetic acid (48, 49), although the reverse was true with *Kerria japonica* (113). Naphthaleneacetic acid, at a given concentration, is more toxic to cuttings of most species than is either of the other two (96, 97).

Naphthylacetamide and naphthylthioacetamide are less toxic than the above-named acids and are fully as effective root-inducing substances with cuttings of some species (97), although with cuttings of some other species, more difficult to root, indolebutyric acid gave better results (104).

Preparation of Solutions of Root-inducing Substances

Solutions, ready for use, are made by dissolving the crystals (previously weighed by the propagator or by a druggist) in a few drops of 95 percent ethyl alcohol which is then diluted with the required amount of water. Naphthaleneacetic acid is difficult to dissolve and may require a period of 48 hours in water, with occasional shaking, to get it all into solution (113), but there is no such delay with indolebutyric acid.

Stock solutions of indolebutyric acid may be prepared for later dilution and, if stored out of the light and in a cool place (16, 88), will keep for weeks (68, 113) without much or any loss in effectiveness. A stock solution which contains indolebutyric acid 200 mg. per liter may, by repeated dilution with equal volumes of water, be reduced to an indolebutyric acid content of 100, 50, 25 or 12.5 mg. per liter (mg./l., as hereafter referred to). Another method (16, 22) consists in dissolving 1 gm. of the crystals in a little 95 percent alcohol, 100 cc. or less, and then adding this to enough water to make a total of 250 cc. There will then be 10 mg. of the root-inducing substance in each 2.5 cc. and the quantities of this stock solution which it is necessary to add to each liter of water to make dilute solutions of the following concentrations will be as follows: 2.5 cc. for 10 mg./l., 5 cc. for 20 mg./l., 7.5 cc. for 30 mg./l., 10 cc. for 40 mg./l., 12.5 cc. for 50 mg./l., 20 cc. for 80 mg./l., and 25 cc. for 100 mg./l. Safe and effective concentrations, named below for cuttings of a number of species, depend upon the species, condition of cuttings, and length (in hours) of treatment but this is probably a sufficient range for most species.

In working with species for which no good treatment is yet known, the propagator, having in mind the concentrations and treatments which are effective with related species, should remember that a treatment which is safe and effective with one species at one time of year may not be for another species, or even for the same species at other times of year (50). In general, the less mature the wood, the lower should be the concentration or the shorter the treatment (16) although cuttings of some species reach their peak of requirement for concentrations, at least of indolebutyric acid, in October and November (49).

Low concentrations of indolebutyric acid are effective with herbaceous

plants; 5 or 10 mg./l., 24 hours, or 2 to 5 mg. per gm. talc being enough, for example, for cuttings of heliotrope, Begonia, and Chrysanthemum (49).

Treatment of Cuttings by the Solution–Immersion Method

The cuttings, usually held in bundles by rubber bands, are set with their basal ends in a solution of root-inducing substance (not in metal containers (58)) about one inch deep and there they remain for a number of hours. Solutions of indolebutyric acid (17, 83) and naphthaleneacetic acid can be used three times if within a week and if most evaporation is meanwhile prevented, but solutions of indoleactic acid may deteriorate more rapidly (99).

Cuttings during treatment should be out of direct sunlight but in good light (17, 79, 81). At night or in very dark weather the length of time of treatment may well be somewhat longer (113).

Moderately dry air and ordinary room temperatures have given good results but the rate of absorption of the chemical varies with humidity and temperature of the air (79) and a shorter treatment in a very warm room may be long enough (125). The temperature of the solution itself may also be a factor. Cuttings of *Thuja occidentalis* var. *ericoides* which were taken here in December rooted the same, 64 percent in seven months, whether or not they were treated with indolebutyric acid (25 mg./l., 20 hrs.) at 68° F., but when this treatment was applied at an initial temperature of 90° F. dropping to 86° F. in one hour and to 68° F. for the following 18 hours, they rooted 100 percent in three months. Rooting of similar cuttings of *Taxus media* and *Picea pungens* var. *globosa* treated for 20 hours with solutions of indolebutyric acid was similarly more improved if the first two hours of the treatment were at 86° F., dropping then to 68° F., than if they were treated at an approximately constant temperature of 68° F.

Cuttings are sometimes rinsed in tap water immediately after this treatment (17, 68, 117) and that was the practice here. In other instances (16, 57), they have been placed directly in the rooting medium without rinsing. It is probable that the first method is safer with high concentrations; perhaps less effective with low concentrations or if length of time of treatment is very short.

The Powder–dip Method of Treatment as Compared with the Solution–immersion Method

Treatment by the powder–dip method consists in dipping the basal half inch of cuttings, previously moistened with water (18, 49, 58, 104), in talc with which a root-inducing substance has been intimately mixed in the proportion of a certain number of milligrams per gram (mg./gm.) talc. Talc alone improves the rooting of cuttings of some species (49, 96) but does not improve it enough. The excess of powder is removed by tapping the cuttings on the inside of the container of the powder, after which they are inserted in the rooting medium just as if they had not been treated (49).

The powder–dip method is quick and convenient, therefore popular; but when cuttings are handled in bundles, solution treatments may have some advantage in convenience and thoroughness of application (99). The powder–dip method has, in some cases (18, 114), given results

inferior to the solution–immersion method, but other investigators (58, 96) have found these methods equally effective if the talc is mechanically fine enough (49, 58, 114) and if the root-inducing substance is applied at optimum concentrations. More than one concentration of root-inducing substance in the powder is needed to meet the requirements of cuttings of different species (58), so no one dust can be ideal for all (96).

Powder preparations of indolebutyric acid which had been in open containers, and in continuous use, for a year were no less effective for treatment of cuttings (of roses) than were freshly prepared mixtures (62).

It may develop that one method is better for some species, another for others (34). The powder–dip method improved the rooting of softwood cuttings of Kurume azaleas, although they were injured by treatment for 24 hours with a very dilute solution of indolebutyric acid (57). The powder–dip method gave satisfactory results with cuttings of a number of species of ericaceous plants but was better than the solution treatment only with male-berry, the cuttings of which rooted very poorly after solution treatment (90). Cuttings of Lantana and Poinsettia are also subject to injury when soaked (18), and the powder–dip method or the concentrated solution–dip method (see below) is better for such species.

Immersion of basal ends of cuttings in water for 24 hours, previous to their insertion in sand or sand–peat, interfered with the rooting of cuttings of Norway spruce (24), Chinese wistaria, *Syringa Prestonae, Jasminum stephanense*, two species of Magnolia, and some other species (18, 125) and had a bad effect on the rooting of leaf-bud cuttings of a raspberry (2).

Not all species react in this way, the cuttings of some being benefited rather than injured by immersion of their basal ends in water for at least a few hours. Softwood cuttings of buttonbush, sweet gale, osage-orange, *Ceanothus Delilianus, Viburnum tomentosum, Fothergilla Gardeni, Hydrangea quercifolia*, and *H. macrophylla* treated for 24 hours with water rooted in larger percentages than did cuttings directly inserted in the rooting medium (87). November cuttings of *Taxus media* var. *Hicksii*, the basal ends of which had stood in water for six weeks before their insertion in sand–peat, rooted 100 percent, as did untreated cuttings, but the best roots developed on the cuttings which had been in water.

It should be noted in this connection that some investigators (16, 47, 117, 119) have treated control cuttings, checks, with water for the same number of hours that other cuttings were immersed in a solution of growth substance; but in the work done here, control cuttings were directly inserted in rooting media without any previous treatment with water for, in practice, cuttings are either treated with a growth substance or not at all.

Concentrated Solution–dip Method of Treatment

Treatment of cuttings by this method consists in merely dipping the basal half inch of cuttings in a concentrated solution containing 1 to 20 mg. root-inducing substance in 1 cc. of water or mixture of water and alcohol (49). Like the powder–dip method this reduces the time of treatment to a few seconds and is said to be about as effective at optimum concentration as the standard or solution–immersion method (49). The last named is, of course, a matter not of seconds but of hours and this is a point of some importance with cuttings of species which may be injured by a prolonged soaking in a solution or even in water.

Root-inducing Substances Sold Under Trade Names

These have given results not significantly different from those secured by the use of the pure chemicals (83, 113). They improve the rooting of cuttings of some species if properly used. That usually means as recommended by the manufacturers, although their recommendations, like those of the experiment stations for use of the pure chemicals, are probably sometimes tentative and may not finally and in all cases prove to be the best (102). Rootone contains alpha naphthylacetamide and the Hormodins contain indolebutyric acid. As with indolebutyric acid, so with Hormodin A, rooting response varies with the season and conditions under which cuttings are taken, treated, and handled (117). One B T I unit in Hormodin A, as now made, is equivalent to indolebutyric acid 1 mg./l., a point of interest when a recommendation for optimum concentration of one of these materials is being followed in diluting the other.

Treatment of Hardwood Cuttings

Hardwood cuttings of most trees and shrubs respond less to treatments with root-inducing substances than do softwood cuttings (25, 57, 114, 130), but rooting of hardwood cuttings of a number of species including grape (130), Tatarian honeysuckle (40), oriental bittersweet (48), black locust (95), poplars (65), and Deutzia (48) has been improved or hastened by treatments. Rooting of hardwood cuttings of common privet was not affected by callusing before treatment (57), but treatment of hardwood cuttings of pecan and some other species was more effective if cuttings were allowed to callus before treatment (95). Such cuttings rooted, if, immediately after treatment, they were packed in moist sand or sphagnum at 68° to 70° F. for a week and then planted in the field (95); and hardwood cuttings of apple, grape, and Hibiscus responded to treatments when buried, after treatment, in damp peat moss at about 75° F. (58).

Deferred Treatment or Re-treatment of Cuttings

Cuttings are usually treated with a root-inducing substance very soon after they are taken if they are treated at all. If, however, they have not rooted, either with or without treatment, cuttings of some species may be removed from the rooting medium and effectively treated, without removing callus (48), weeks or months after they were first inserted. Such treatments are called "deferred" if applied for the first time; "re-treatments" if applied for the second time.

Rooting of cuttings of box, Japanese yew, and a variety of *Camellia japonica* was improved when treatments were first applied to cuttings six weeks to five months after they were taken (48). A treatment first applied to cuttings of American holly after they had remained unrooted in the bench for eleven weeks was beneficial (101). A first treatment of cuttings of incense cedar (see page 25) with indolebutyric acid fifteen months after they were taken was decidedly effective.

Cuttings of some species which respond little or not at all to an initial treatment will root or root better if re-treated (61). Rooting of cuttings of Hamlin sweet orange was improved by re-treatment three weeks after the initial treatment (19). Re-treatment of cuttings of papaya and Camellia (19), after callus had formed on the latter (61), gave similar results. Other species which responded well to re-treatment are Japanese yew and Pfitzer's juniper (59).

Use of Potassium Permanganate

Potassium permanganate has a decidedly beneficial effect on the rooting of cuttings of some species. A solution, one pound in fifteen gallons of water, applied to the rooting medium at the rate of two quarts per square foot, resulted in better roots on cuttings of twenty-three out of twenty-five species and in increased percentages of rooting of softwood cuttings of arrow-wood, dockmackie, flowering dogwood, Tatarian honeysuckle, Japan quince, dwarf flowering almond, *Cornus racemosa*, *Magnolia Soulangeana*, *Viburnum Carlesii*, *Malus atrosanguinea* and *Philadelphus coronarius* (14). When potassium permanganate, 18 gm. per square foot, was well worked into sand–peat before the insertion of cuttings taken here in October, they rooted as follows:

	Percentage Rooting	
	With Potassium Permanganate	Without It
Euonymus patens	100	80
Taxus media	93	40
Ilex crenata	100	60
Thuja occidentalis var. *Columbia*	86	53

The good effects of potassium permanganate, not due to any soil-disinfecting action (26), are also marked when it is applied to cuttings of some species rather than to the rooting medium. Rooting of cuttings of black-alder, common privet, and Japanese yew was improved by treatment for 24 hours with a solution of one ounce in five gallons water (14), and treatment of cuttings of Kudzu-vine for thirty minutes with a solution of one ounce in eight gallons water improved their rooting more than did treatment with an ordinary root-inducing substance (75).

Cuttings should not be treated with both potassium permanganate and a root-inducing substance, for the former has a somewhat inactivating effect on the later (109).

Use of Sugar

Sugar, common table sugar, alone or in combination with a root-inducing substance, is of benefit in the rooting of cuttings of some species. Treatment for 24 hours with a sugar solution (one pound in seven gallons water) improved the rooting of cuttings of black-alder, common privet, and Japanese yew (14). October cuttings of ninebark produced longer roots after treatment with sugar and a root-inducing substance than after treatment with the latter alone (37). Cuttings of white ash and white pine lived for a longer time if, after treatment with a root-inducing substance, they were immersed for three days in a 5 percent sugar solution (109). Cuttings of *Picea glauca* var. *conica* which were taken here in December rooted 39 percent without treatment, 64 percent after treatment (24 hr.) with indolebutyric acid 50 mg. in one liter of water, 84 percent after that treatment followed by treatment (24 hr.) in 2.5 percent sugar solution, and 84 percent after treatment (24 hr.) in a solution of 50 mg. indolebutyric acid in one liter of 2.5 percent sugar solution. Cuttings were in all cases well rinsed in water upon their removal from sugar solutions. Rooting of November cuttings of Pfitzer juniper and two varieties of *Chamaecyparis obtusa* was more improved by treatment for 20 hours with indolebutyric acid

50 mg./l. in 2.5 percent sugar solution than by this concentration of the acid in water. Similar cuttings of *Taxus media* rooted in equally large percentages after treatment for 17 hours with indolebutyric acid 100 mg./l. in water and in the sugar solution, but cuttings given the latter treatment had better roots. Rooting of cuttings of two varieties of arbor-vitae and three varieties of Norway spruce, however, was no better after treatment with solutions containing both sugar (2.5 percent) and indolebutyric acid than after treatment with a solution of indolebutyric acid only.

Acetic Acid

Vinegar or dilute acetic acid has long been recommended in horticultural literature as a treatment for cuttings or rooting media. It may have somewhat improved the rooting of cuttings of some species but, if so, the improvement was probably slight compared with that which, with some species, results from the use of such growth substances as indolebutyric acid (3); and in the work of other investigators (48, 113), acetic acid has been totally ineffective.

Rooting Media

Sand or a mixture of sand and peat moss are most commonly used. The latter, referred to as sand–peat, sometimes consists of equal parts of sand and peat moss, but it gave better results and was usually made and used here in the proportion of sand two parts (by volume, in all cases) and peat moss one part. There is probably no better rooting medium than sand–peat for cuttings of ericaceous plants, although, for some species, their native soil may be as good, and sand–peat is a better rooting medium than sand for cuttings of the majority of woody plants (58). But softwood cuttings of many species, including a number of those named below, have rooted better in sand than in sand–peat.

German peat moss is now practically unobtainable. Some native peats will do as well, but, lacking both, more use might well be made of sandy soil. Sandy soil, a mixture of sand two parts and sifted loam one part, is a good rooting medium for cuttings of some, not all, species of woody plants (27). It is also sometimes used as a rooting medium for cuttings of some herbaceous plants, but the risk of attack by soil fungi in that medium, unsterilized, might be greater with them than with cuttings of woody plants and only the latter are here considered.

The good effect of loam in a rooting mixture (27) may be due to the presence of indoleacetic acid (34) or other root-inducing substance. Soil fungi in an organic medium are known to produce auxin (86), and the reaction of plants to applied hormones was less marked in good soil than in sand (34). Nutrients in loam may also be a factor. Their application to sand improved the rooting of cuttings of Norway spruce (36) and a honeysuckle (40). It is possible too that vitamins are involved. Cuttings of Asiatic sweet-leaf and Pfitzer juniper rooted better in the sandy soil which was used here than they did in sand and these are both species the cuttings of which responded to applications of vitamins to sand (98, 103).

It should be noted, in this connection, that Vitamin B_1 has had little if any effect on the rooting of cuttings not previously treated with a root-inducing substance (103, 109, 114), and that treatment of cuttings with Vitamin B_1 after their treatment with a root-inducing substance did not

affect their rooting (50), but that when a solution 1:1,000,000 was used to water sand in which treated cuttings of Japanese yew and Pfitzer juniper had been planted twelve days previously, their rate of rooting was significantly increased (103). Vitamin B_6, in a solution of 1:5,000,000, similarly applied to sand once a week, hastened rooting and caused cuttings to retain leaves better in the case of about one-third of the species with which it was used (98).

In any case, or without regard to the explanation, the addition of loam to sand has a good effect on rooting of cuttings of some species. Whether or not the results would be even better if the loam were first sterilized was not determined, but the risk of trouble from that quarter may be less great than might be expected. It is interesting to note that cuttings of woody plants sometimes root better in old sand—sand which has been used for rooting cuttings and is probably contaminated, certainly not clean—than they do in new, fresh sand (113), and that cuttings of azaleas (44) and Erica (105) rooted better in a medium in which they had previously been rooted or grown than in one freshly prepared.

Insertion of Cuttings and Their Subsequent Care

Cuttings are inserted firmly in the rooting medium, usually as deeply as possible without burying the leaves. Leafy cuttings of most woody plants are likely to do best if inserted slantingly, not vertically, for, in the slanting position, more of the leaves are near or upon the rooting medium where there is less danger of the air being too dry. If there is much top growth before rooting or transplanting, cuttings so set may not have straight stems, but that risk is slight except with the most actively growing material.

To help prevent wilting, cuttings in bench or frame are usually shaded with cheesecloth or whitewashed glass and sprinkled with water several times a day, a practice which is likely to give better results than heavier and less frequent waterings. Good temperatures of the air are 70° to 80° F. days, 60° to 65° F. nights (130). Bottom heat, 70° to 73° F. often hastens rooting (49). It was used here in fall, winter, and spring but, because of high air temperatures, not in summer. Bottom heat at 70° to 75° F. gave better results than at 80° to 85° F. with cuttings of Japanese yew and Pfitzer juniper (103), and temperatures of 75° to 80° F. are known to be too high for best rooting of cuttings of some other species (49).

The most effective temperatures for rooting treated cuttings are between 70° and 80° F. and root-inducing substances are without much effect if cuttings, after treatment, are given a low temperature (49, 58), 60° F. or lower (61).

Treated cuttings need no less care than untreated, although, if treatment is effective, they may not need it for so long a time.

Results with Individual Species

Abelia grandiflora. Softwood cuttings root readily, but treatments with indolebutyric acid (10 mg./l., 24 hr., or 2 mg./gm. talc) (61) may hasten rooting. Taken here in early August, they rooted 100 percent in 7 weeks without treatment, in 4 weeks with treatment (12.5 mg./l., 24 hr.). Rooting of July cuttings was similarly hastened by treatment with Hormodin (102).

Abeliophyllum distichum. Untreated hardwood cuttings which were taken here in mid-March and immediately inserted in sand–peat rooted 63 percent in 10 weeks.

Abies, fir. February cuttings of Colorado fir, untreated, rooted 60 percent in peat moss, little or not at all in sand–peat or sand (67). Sandy soil is the English rooting medium (7). Rooting of winter cuttings of Spanish fir and Veitch fir was improved by treatment with indolebutyric acid 40 to 80 mg./l., 24 hr., or 12 mg./gm. talc (61). Cuttings of Spanish fir also responded to treatment with 10 to 20 mg./cc. applied by the con-
60 percent without treatment (87).

Acanthopanax Sieboldianus. Late June cuttings rooted 73 percent in 27 days after treatment with indolebutyric acid (20 mg./l., 24 hr.), not at all meanwhile without treatment (57). August cuttings rooted 50 percent in 55 days without treatment, 80 percent with treatment (100 mg./l., 20 hr.) (83).

Acer, maple. Hardwood, late November, cuttings of silver maple which were buried in a cool place until February and then planted in sand at 72° F. rooted 84 percent (52). Hardwood, late winter or early spring, cuttings of *A. barbinerve, A. caudatum, A. cissifolium, A. rufinerve,* and *A. Tschonoskii* rooted 20 to 80 percent in 4 to 9 weeks in sand at 70° to 74° F., bottom heat (111).

The best time to take softwood cuttings of maples is probably late spring and early summer. Cuttings of *Acer argutum, A. barbinerve,* box-elder, and Japanese maple which were taken, with a heel, when oldest leaves were no more than half grown rooted 35 to 100 percent in sand in 18 to 60 days (111). Such cuttings responded to treatments with indolebutyric acid. Equivalent concentrations for June cuttings of Japanese maple are 2 to 5 mg./gm. talc or 10 to 40 mg./l., 24 hr. (49). Early July cuttings of red maple rooted 60 percent after treatment (20 mg./l., 24 hr.), not at all without it (1). June cuttings of silver maple rooted 85 percent after treatment (50 mg./l., 32 hr.), not at all without it (65). June cuttings from very young Norway maples responded slightly to treatment with indoleacetic acid (100 mg./l., 24 hr.) (109). Cuttings of sugar maple, taken in early summer, rooted 100 percent in sand–peat in 40 days after treatment with indoleacetic acid (10 mg./l., 48 hr.), 33 percent without treatment (87). Snow (92) took cuttings of sugar maple from young trees, made them four inches long with all leaves but the upper removed, and set them deeply in sand–peat in an outdoor propagating frame. By the end of summer, the cuttings which he took in mid-June had rooted 25 to 36 percent without treatment and about 66 percent after treatment with indolebutyric acid (50 mg./l., 3 hr.). Results were decidedly less good with cuttings taken in July.

Actinidia. Cuttings are taken in summer and fall. September cuttings of *A. arguta,* in sand, rooted 86 percent in one month after treatment with indolebutyric acid (5 mg./l., 24 hr.), 42 percent without it (96). Equivalent concentrations for treatment of December cuttings are 20 to 40 mg./l., 24 hr.; 4 to 10 mg./gm. talc; or, by the concentrated solution–dip method, 1 to 4 mg./cc. (49). July cuttings of *A. chinensis,* in sand–peat, rooted 100 percent in 40 days after treatment with indoleacetic acid (100 mg./l., 48 hr.), 60 percent without treatment (87).

Alnus, alder. Cuttings, which do not root very readily, are taken in autumn as soon as the leaves fall and inserted in sandy soil (7).

Amelanchier, shadbush, is not easily propagated by cuttings (51). Softwood, summer cuttings of one species rooted 25 percent after treatment with indoleacetic acid (50 mg./l., 24 hr.), 8 percent without it (65). There is some evidence that *A. canadensis* can be propagated by hardwood cuttings taken in April and set in a solar frame (85).

Amorpha fruticosa. Softwood, July cuttings, made with the basal cut at a node and planted untreated in sand, rooted 100 percent (116).

Andromeda, bog-rosemary. Untreated cuttings of *A. glaucophylla* and *A. Polifolia* which were taken here in January rooted 100 percent in 8 weeks in sand–peat, less well in sand, and treatments with root-inducing substances were without effect.

Arctostaphylos Uva-ursi, bearberry. Untreated cuttings taken here in January rooted 86 percent in sand in 12 weeks. February cuttings rooted best, about 90 percent in 74 days, when multiple terminal cuttings (those having three or more shoots on one branch) were treated and inserted in sand–peat with bottom heat at 76° F. (22). Treated October cuttings rooted better if made of basal parts of shoots rather than of their tips (48). Effective concentrations of indolebutyric acid are 40 mg./l., 24 hr., or 12 mg./gm. talc (61).

Aristolochia. September cuttings of one species, untreated, rooted 75 percent in sand in 26 days (98). Dutchman's pipe is more readily propagated by softwood, summer, than by hardwood cuttings (80).

Aronia, chokeberry. Softwood, summer cuttings of red chokeberry root in good percentages (42). Cuttings of that species and of black chokeberry gave best results when the basal cut was made a half inch below a node (14).

Berberis, barberry. Cuttings are taken in summer or fall. August cuttings of *B. Thunbergii* (44), the basal cut a half-inch above the base of the current season's growth (46), root readily in sand–peat. Cuttings of evergreen species may well be taken later than those of the deciduous (105). There was 100 percent rooting of untreated cuttings of *B. candidula* and *B. triacanthophora* which were taken here in late November and inserted in sandy soil, the medium used for barberry cuttings in England (7, 105). December cuttings of *B. verruculosa* rooted well in sand (67). Rooting of July cuttings of that species was at least hastened by indolebutyric acid (83). Cuttings of *B. Sargentiana* rooted 80 percent in 51 days after treatment with indolebutyric acid (50 mg./l., 24 hr.), 60 percent without it (72). Hormodin No. 2 improved rooting of cuttings of *B. Julianae* (102).

Betula. Birches are not easy to propagate by cuttings (73), but treated softwood cuttings will root to some extent. Summer cuttings of European birch rooted 25 percent after treatment with indoleacetic acid (50 mg./l., 32 hr.), not at all without it (65). Cuttings of gray birch taken in July, with the terminal buds and all but one or two square inches of leaf area removed, rooted 30 percent after treatment with indolebutyric acid (50 mg./l., 6 hr.); and cuttings of canoe birch rooted 50 percent after treatment with indolebutyric acid (20 mg./l., 24 hr.) (1).

Buddleia, butterfly bush, is easy to propagate by cuttings. Taken here in late June or early July and inserted untreated in sand, cuttings of *B. alternifolia* rooted 83 percent and cuttings of *B. Davidi* rooted 100 percent. Treatment with indolebutyric acid (33 mg./l., 24 hr.) hastened the rooting of June cuttings of *B. alternifolia* (114).

Buxus, box. Untreated summer (67), fall (44, 125), or winter cuttings of *B. sempervirens* root very readily in sand (105, 125) or sandy soil (127). Rooting of July (57), October (125), and February cuttings of *B. sempervirens* was hastened by treatment but not otherwise affected. Optimum concentrations of indolebutyric acid are 40 mg./l., 24 hr., for that species and 20 mg./l., 24 hr., for *B. microphylla*, or 12 mg./gm. talc for either (61).

Callicarpa is easy to propagate by both softwood and hardwood cuttings. Hardwood cuttings of *C. dichotoma* taken here in early January rooted 100 percent in sandy soil in two months without treatment and in one month after treatment with indolebutyric acid (40 mg./l., 18 hr.). Untreated summer cuttings of that species root in high percentages in sand (44, 125), but rooting of August cuttings was hastened by treatment with indolebutyric acid either in talc or 5 mg./l., 24 hr. (96). Late June cuttings of *C. Bodinieri* rooted 100 percent in 20 days after treatment (5 or 10 mg./l., 24 hr.) (57). Tips of shoots of *C. japonica* gave better results (59) and responded better to low concentrations than did cuttings made of basal parts (48).

Calluna vulgaris, heather. Summer, fall, and winter cuttings root well without treatment. Untreated cuttings taken here in September, November, and January rooted 90 to 100 percent in sand–peat in 6 to 8 weeks, more slowly or less well in sand or sandy soil. Optimum concentrations of indolebutyric acid are 20 to 40 mg./l., 24 hr., or 12 mg./gm. talc (61).

Camellia japonica is not very difficult to propagate by cuttings taken in July, or when new growth is only moderately hard, and planted in sand–peat (30). Cuttings of the variety *alba plena* are less easy to root, but cuttings of some other varieties root readily enough after treatment (49) with indolebutyric acid 40 to 80 mg. /l., 24 hr., 12 mg./gm. talc (61), or 4 to 10 mg./cc. by the concentrated solution–dip method (49). July cuttings rooted 100 percent in 10 weeks after treatment (100 mg./l., 24 hr.) (114). Stevens* got equally good rooting of cuttings made of somewhat harder wood following treatment with indolebutyric acid (60 mg./l., 24 hr.). He got better rooting in sand–peat than in sand, better rooting with bottom heat at 70° to 75° than at 60° F.

Caragana. Late July cuttings of pea-tree, treated or not, rooted more than 80 percent in sand (102). Equivalent concentrations of indolebutyric acid for May cuttings of *C. Boisii* are 10 mg./l., 24 hr., or 4 mg./cc. by the concentrated solution–dip method, or 2 to 5 mg./gm. talc (49).

Carya Pecan, pecan. Hardwood, early April, cuttings of the variety Posey, made of wood two to four years old, were allowed to callus in moist sphagnum at 68° to 78° F. for about three weeks, then treated with indolebutyric acid (100 mg./l., 24 hr.) and set in sand at 70° F. bottom heat, where large cuttings, a half inch in diameter, rooted 63 percent (95). Smaller cuttings rooted less well and there was no rooting of the untreated. Equivalent concentrations for treatment of such cuttings are 40 mg./l., 24 hr., or 2 to 12 mg./gm. talc (49).

Catalpa. These can be propagated by softwood, summer cuttings in sand (105). Untreated cuttings of western catalpa rooted 77 percent (33). Equivalent concentrations of indolebutyric acid for April cuttings are 5 to 12 mg./gm. talc or, by the concentrated solution–dip method, 4 mg./cc. (49).

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*Stevens, Robert F. The genus Camellia with special reference to the propagation by cuttings. Thesis submitted for the degree of Master of Science, Massachusetts State College, May 15, 1938.

Ceanothus. Cuttings root readily in sand if taken in summer (105), September (51), or earlier. July cuttings of *C. Delilianus* rooted 100 percent in 30 days after treatment with indoleacetic acid (100 mg./l., 24 hr.), 40 percent if untreated (87). Rooting of fall cuttings was hastened by treatment with 20 mg./l., 24 hr. (113).

Cedrus libani, cedar of Lebanon, is not easily propagated by cuttings (61) although there is some rooting of those taken in the fall (80) Untreated cuttings taken here in November rooted 30 percent in sand–peat, less well in sand.

Celastrus. Untreated softwood cuttings of American bittersweet root readily in sand (125) but treatment may hasten rooting. July cuttings rooted 90 percent in 70 days without treatment and in half that time after treatment with indolebutyric acid (50 mg./l., 20 hr.) (125). Their rooting was similarly hastened, 100 percent rooting in 50 days, by treatment with 30 mg./l., 6 hr. (83). Hardwood, April cuttings of oriental bittersweet produced more roots after treatment with indolebutyric acid (40 mg./l., 24 hr.), and there was even more benefit by naphthaleneacetic acid (48). Equivalent concentrations of indolebutyric acid for treating hardwood, winter cuttings of this species are 40 mg./l., 24 hr.; 2 mg./gm. talc; or, by the concentrated solution–dip method, 1 to 4 mg./cc. (49).

Cephalanthus occidentalis, buttonbush. Cuttings taken here in late July and early August rooted 100 percent in sand–peat in one month whether or not they were treated. Hardwood cuttings also root readily (51).

Cercis, redbud. Softwood cuttings of *C. chinensis* and *C. canadensis* which were taken in June or July, or when one leaf of the new growth was almost full grown and the smallest leaves of *C. canadensis* were about a half inch in diameter, rooted 75 to 90 percent in sand at 72° F. in about four weeks (111).

Chaenomeles. Japan quince has been considered difficult to propagate by cuttings (113) but treated softwood cuttings, taken in late spring or early summer, root well. Those which were taken here in early June, when fruits were about a half inch in diameter, rooted at least 90 percent in sand in four weeks after treatment with indolebutyric acid (12.5 mg./l., 24 hr.), not more than 30 percent without treatment. Rooting of July cuttings of *C. japonica* was hastened by treatment with naphthaleneacetic acid, 1:1000, in talc (104).

Chamaecyparis Lawsoniana, Lawson cypress, is easily propagated by fall cuttings. Untreated, they rooted 90 percent or more in sand–peat when taken here in October, equally well but more slowly when taken in January. Rooting of cuttings of the variety *Fletcheri* was improved by indolebutyric acid 40 to 80 mg./l., 24 hr., or 12 mg./gm. talc (61).

Chamaecyparis obtusa, Hinoki cypress. Rooting of cuttings of the varieties, sometimes poor otherwise, is better if they are treated with indolebutyric acid (40 to 80 mg./l., 24 hr., or 12 mg./gm. talc) (61). Cuttings of the varieties *nana* and *compacta* which were taken here in November rooted, in sand–peat, not more than 40 percent in 12 months without treatment, not less than 90 percent in 5 months after treatment (100 mg./l., 20 hr.). Rooting of late December cuttings of the varieties *magnifica* and *filicoides* was similarly improved by 50 mg./l., 24 hr. Cuttings of the varieties named rooted in about the same percentages when taken here in October, November, and December. Cuttings of the variety *compacta* which were taken here in mid-July rooted 22 percent without treatment, 55 percent after treatment

with indolebutyric acid (25 mg./l., 16 hr.). Untreated cuttings of the variety *filicoides* rooted better in sand–peat than in sandy soil, better in sandy soil than in sand.

Chamaecyparis pisifera, Sawara cypress. Cuttings of the variety *plumosa* rooted well in sand–peat or sand if taken in November or December, less well if taken in February (31). Treated cuttings rooted equally well in sand–peat when taken here in October, November, or December, less well in sand. Effective treatments for cuttings of five varieties were indolebutyric acid 40 to 80 mg./l., 24 hr., or 12 mg./gm. talc (61). Cuttings of the varieties *filifera* and *squarrosa* which were taken here in late November rooted 90 to 100 percent after treatment with indolebutyric acid (75 mg./l., 24 hr.), 45 to 63 percent, and more slowly, without treatment. October cuttings of the variety *plumosa* rooted 100 percent in 12 weeks with that treatment and in 19 weeks without treatment.

Chamaecyparis thyoides, white cedar, has not been easy to propagate by cuttings (5), but cuttings which were taken here in mid-November and treated with indolebutyric acid (125 mg./l., 24 hr.) rooted 96 percent in sand–peat in 6 months. Results were less good with lower concentrations, and only 33 percent of the untreated cuttings rooted.

Chiogenes hispidula, creeping snowberry. Cuttings root readily. Taken here in mid-July and not treated, they rooted 100 percent in sand–peat in 8 weeks, less well in sand.

Cladrastis lutea, yellow-wood. Untreated softwood, summer cuttings rooted 100 percent in sand–peat in 6 weeks (87).

Clematis. Cuttings are taken in summer, late summer in the case of most of the small-flowered kinds (71). Untreated cuttings of *C. lanuginosa*, in sand or sandy soil, rooted more than 90 percent in 45 days when taken here in late June and early July. Cuttings of *C. Lawsoniana* and *C. tangutica* are successfully taken in July (116). Cuttings root equally well with the basal cut made at a node or between two nodes, and single node, internodal, cuttings of the large-flowered sorts give good results (71). June cuttings of *C. vedrariensis* which had been treated with indolebutyric acid (33 mg./l., 24 hr.) rooted 75 percent more in 3 weeks than did untreated cuttings. Indoleacetic acid (100 mg./l., 18 hr.) hastened the rooting of cuttings of *C. montana* var. *rubens* (20).

Clethra alnifolia, sweet pepperbush. Summer cuttings root readily (113), up to 100 percent in sand–peat, less well in sand, without treatment (66) but treatments may hasten rooting. Late June cuttings rooted 100 percent in 20 days after treatment with indolebutyric acid (10 mg./l., 24 hr.) (57).

Coriaria. Early July cuttings rooted 85 percent in sand in 18 days after treatment with naphthaleneacetic acid (1:1000, in talc), about 57 percent without treatment (97).

Cornus alba. Late June cuttings rooted 80 percent in 30 days after treatment with indolebutyric acid (50 mg./l., 24 hr.), not at all meanwhile without it (57).

Cornus Amomum. July cuttings rooted so well without treatment that the only result of treatment (indolebutyric acid 30 mg./l., 20 hr.) was more roots per cutting (125).

Cornus florida, flowering dogwood. Untreated cuttings rooted 100 percent in 3 weeks if taken in spring when flowering period was ending, less well if taken later (111). June cuttings rooted equally well with or without

a heel (46), more quickly with four leaves than with two (111); but if there is much danger of wilting, half the leaves may well be removed (57). Cuttings root well in sand (57, 111), sometimes better in sandy soil. Taken here in early June, they rooted 47 percent in sand, 64 percent in sandy soil without treatment; 73 percent in sand, 95 percent in sandy soil in 34 days after treatment with indolebutyric acid (12.5 mg./l., 24 hr.). Other effective concentrations are 10 mg./l., 24 hr. (57) or 5 mg./gm. talc. (49).

Cornus Kousa has not been considered easy to propagate by cuttings (64) but, treated, they root fairly well in sandy soil. Taken here in early July, untreated cuttings rooted 20 percent in sand, 53 percent in sandy soil; and those treated with indolebutyric acid (25 mg./l., 24 hr.) rooted, in 8 weeks, 62 percent in sand, 82 percent in sandy soil. Tips of shoots make good cuttings (105).

Cornus mas, Cornelian cherry, is less readily propagated by cuttings than some dogwoods (116), although they root sometimes fairly well in sand (44, 66), better in sandy soil. Untreated cuttings which were taken here in mid-July rooted only 25 percent in either medium; those which had been treated with indolebutyric acid (25 mg./l., 20 hr.) rooted 100 percent in sandy soil, but no better than the untreated in sand.

Cornus racemosa. Cuttings rooted 66 percent following treatment with indolebutyric acid (80 mg./l., 4 hr.), much less well without it (125). Rooting of July cuttings was improved by naphthaleneacetic acid dust, 1:1000 (102).

Cornus sanguinea, red dogwood. Late June cuttings rooted 68 percent in 3 weeks after treatment with indolebutyric acid (30 mg./l., 12 hr.), 44 percent without it (83).

Cornus stolonifera, red-osier dogwood. Hardwood cuttings, treated or not, rooted 90 percent in 8 weeks when taken here in mid-April and immediately set in the field. Softwood cuttings, whether or not they were treated, rooted 100 percent in 5 weeks when taken here in early August.

Coronilla Emerus, scorpion senna. Summer (51) or early fall cuttings root in sand without difficulty (105). Taken here in early September and early October, untreated cuttngs rooted about 70 percent.

Corylopsis. Softwood, late spring cuttings root well if taken while young shoots are still growing (107). Untreated cuttings of *C. pauciflora* which were taken here in early and mid-June, with basal cut at base of the current year's growth, rooted 100 percent in sand–peat in 8 weeks, less well in sandy soil. Summer cuttings of *C. Willmottiae* rooted about 60 percent more after treatment with indolebutyric acid (17 mg./l., 24 hr.) than did untreated cuttings (113).

Corylus, hazel. Hardwood, early spring, cuttings of European hazel will root if kept fresh and in good light after leaves appear (128). Softwood, summer cuttings rooted 22 percent after treatment with indoleacetic acid (100 mg./l., 24 hr.), not at all without it (65). Mid-July cuttings of a filbert rooted 52 percent in 58 days after treatment with indolebutyric acid (4 mg./gm. talc), not at all meanwhile without treatment (104); and mid-June cuttings of European hazel responded to treatment with indolebutyric acid, 5 mg./gm. talc (49).

Cotoneaster. Softwood cuttings are taken in late spring or early summer. Untreated cuttings of *C. divaricata* rooted 100 percent in 7 weeks when taken

here July 1 and there was good rooting of cuttings of *C. acutifolia, C. horizontalis* (14), and *C. adpressa* (67) taken at or about that time. Cuttings of harder wood are also used. Those of *C. microphylla* rooted 100 percent when taken here in September. Cuttings of *C. horizontalis* which were taken here in early August rooted 61 percent without treatment, 74 percent after treatment with indolebutyric acid (50 mg./l., 16 hr.). Rooting of October cuttings of *C. microphylla* was merely hastened by similar treatment (125). Sand is a good rooting medium for that species (125), and it is better than sand–peat for summer cuttings of *C. divaricata* and *C. horizontalis.*

Cryptomeria japonica. Summer and fall cuttings will root, although slowly (124). Effective concentrations of indolebutyric acid for December cuttings are 40 to 80 mg./l., 24 hr., 4 to 10 mg./cc. by the concentrated solution–dip method (49), or 12 mg./gm. talc (61).

Cupressus macrocarpa, Monterey cypress. Cuttings responded to treatment with indolebutyric acid 40 to 80 mg./l., 24 hr., or 12 mg./gm. talc (61).

Cydonia oblonga, quince. Softwood cuttings which were treated with indolebutyric acid (20 mg./l., 24 hr.) rooted well if taken in spring while still growing but not if taken a little later than that (81).

Cytisus. Cuttings are made of nearly ripe wood (7) in late summer or fall. Cuttings of *C. Beanii* and *C. purgans,* treated or not, rooted more than 90 percent in sand when taken here in early November. It is English practice to root cuttings in sandy soil and to make them with a heel (80, 105). Cuttings of *C. supinus,* made without a heel, rooted better with the basal cut a half inch below a node rather than at or above one (14). Cuttings of a hybrid which were taken here in late October rooted 69 percent without treatment, 100 percent after treatment with indolebutyric acid (75 mg./l., 20 hr.). Rooting of cuttings of one species was improved by treatment with indoleacetic acid (40 mg./l., 24 hr.) (47).

Daphne. D. Genkwa is easily propagated by cuttings taken while still very soft (108). *D. Mezereum,* mezereum, can be propagated, although not very easily (73), by cuttings taken in the fall (51). Fall, November, cuttings of *D. Laureola* rooted 100 percent in 12 weeks after treatment with indoleacetic acid (50 mg./l. 24 hr.) (68). Fall cuttings of *D. odora* rooted 80 percent in 6 weeks after treatment with indoleacetic acid (100 mg./l., 18 hr.), 14 percent without treatment (25). *D. Cneorum* can be propagated by cuttings taken in summer or in fall. Untreated cuttings taken here in July and December rooted more than 80 percent in sand, less well in sand–peat. December cuttings rooted 56 percent in 6 weeks after treatment with indoleacetic acid (100 mg./l., 16 hr.), not at all meanwhile without treatment (21). Summer cuttings are not very responsive to treatments with indolebutyric acid (83, 125). Rooting of cuttings taken here in September was at least hastened, however, by 50 mg./l., 5 hr., for, in 9 weeks, with some unrooted cuttings still living, there was 66 percent rooting of treated cuttings, 20 percent rooting of the untreated.

Davidia involucrata, dove-tree. Cuttings, made of side shoots or twigs with a heel (80), are taken in late summer (8) or when the wood is firm (105). Their rooting, usually not good (64), was somewhat improved by treatment with indoleacetic acid (100 mg./l., 24 hr.) (87).

Deutzia. Untreated softwood, July, cuttings of *D. Lemoinei* (66) and *D. gracilis* (14) rooted 100 percent in sand but rooting of similar cuttings of *D. scabra* was at least hastened by naphthaleneacetic acid or indolebutyric acid (1:1000, in talc), the former giving the better results (34) Hardwood,

January, cuttings of one species developed more roots per cutting after treatment with naphthaleneacetic acid (60 mg./l., 24 hr.) and there was similar, although less response to indolebutyric acid (48).

Dorycnium hirsutum. Taken here in September and October, untreated cuttings rooted 100 percent in sand in 3 months.

Elaeagnus. Cuttings of *E. pungens* rooted 72 percent without treatment, 100 percent in sand if treated with indolebutyric acid (30 mg./l., 4 hr.) and taken in October; less well if taken earlier or later (125). January cuttings rooted 30 percent without treatment, 75 percent after treatment with indolebutyric acid (40 mg./l., 6 hr.) (119). The species are also propagated by softer wood, summer cuttings made with a heel (80).

Enkianthus. Untreated softwood cuttings of *E. campanulatus* and *E. perulatus* rooted 80 percent or more when taken here in late May. Cuttings of the former taken here in early June rooted 100 percent in 6 weeks after treatment with indolebutyric acid (50 mg./l., 20 hr.), 83 percent in 10 weeks without treatment. Sand–peat is a better rooting medium than sand (44).

Epigaea repens, mayflower. August or September cuttings, made to include the current year's growth and, at the base, some of that of the previous year, rooted in high percentages in sand–peat, peat, sphagnum, or their native soil, and in higher percentages than did cuttings taken in spring (6). Untreated cuttings which were taken here in late August rooted 94 percent in sand–peat in about 5 weeks. Treatment is unnecessary, but the rooting of October cuttings was hastened by naphthaleneacetic acid (50 mg./l., 24 hr.) (114).

Erica, heath. Summer cuttings root readily in a sandy, peaty soil (105) or in sand–peat. Untreated cuttings of cross-leafed heath rooted 93 percent in 8 weeks when taken here in late June, less well when taken in August. Rooting is sometimes improved or hastened by indolebutyric acid (40 mg./l., 24 hr. or 12 mg./gm. talc) (61). July cuttings of *E. darleyensis* rooted 100 percent in 4 weeks with treatment, 77 percent without it (88).

Euonymus, spindle-tree. Softwood, summer, cuttings of evergreen species usually root readily, more readily than those of the deciduous species (7), and cuttings of both may be taken later and rooted in sand. Untreated cuttings of *E. japonica* which were taken here in October rooted 100 percent. October cuttings of *E. kiautschovica* (125) also rooted well. Hardwood cuttings of winged spindle-tree which were taken here in early April and immediately set in the field rooted 100 percent in 4 months whether or not they were treated. November and March cuttings of that species and of *E. latifolia* also rooted well (29). Rooting of cuttings of several species was hastened by treatment with indolebutyric acid (16, 49, 83, 125), concentrations to which there was a response being as follows: European spindle-tree (August), 100 mg./l., 24 hr.; *E. japonica* (September), 60 mg./l., 24 hr.; strawberry-bush, winged spindle-tree, and *E. kiautschovica* 5 to 10 mg./l., 24 hr.; *E. Fortunei,* 1 to 5 mg./gm. talc

Exochorda, pearl bush. Softwood, June or July, cuttings will root although not very well (7,105). July cuttings of *E. racemosa* rooted 40 percent in sphagnum peat, not at all in sand (66).

Fagus, beech. Cuttings do not root at all readily (73), but European beech has been propagated by softwood cuttings taken in early summer when the last one or two leaves on the twig were beginning to develop (42, 67).

Such cuttings responded to treatment with indoleacetic acid (200 mg./l., 24 hr.), 50 percent of them rooting in sand–peat in 37 days (87).

Fontanesia Fortunei is easily propagated by softwood cuttings. Taken here in mid-July, they rooted 100 percent in sand in 8 weeks without treatment. Sandy soil may also be used (80). Late June cuttings rooted 53 percent in 3 weeks after treatment with indolebutyric acid (5 mg./l., 24 hr.), less well with greater concentrations (57).

Forsythia, golden bell. The species are easily propagated by hardwood and softwood cuttings. Untreated cuttings of *F. intermedia* (14) and *F. viridissima* (66) rooted 100 percent when taken in July; also very well, in sand, when taken from May through September (44). Rooting of late June cuttings was hastened by treatment with indolebutyric acid, *F. suspensa* responding to 50 mg./l., 6 hr. (83) and *F. intermedia* to 5 mg./l., 24 hr. (57).

Fothergilla. Cuttings are considered difficult to root (73), but July cuttings of *F. Gardeni* rooted 100 percent in sand–peat in 42 days after treatment with indoleacetic acid (200 mg./l., 24 hr.), 67 percent without it (87). Untreated softwood cuttings of *F. monticola* which were taken here in spring, when the shrubs were in flower, failed to root in sand but rooted 67 percent in sandy soil in 60 days.

Franklinia alatamaha (*Gordonia*) is not difficult to propagate by late summer or fall cuttings. August cuttings rooted 83 percent in sand in 29 days after treatment with indolebutyric acid (30 mg./l., 24 hr.), equally well but more slowly without treatment (125). Cuttings which were taken here in early November rooted 93 percent in 64 days after treatment with indolebutyric acid (50 mg./l., 24 hr.), 67 percent without it; and these November cuttings proceeded to make more top growth than did cuttings taken in August.

Gardenia. Cuttings respond to treatment with indolebutyric acid (40 mg./l., 24 hr. or 2 mg./gm. talc) (61) but sometimes the only effect is to hasten rooting. Untreated cuttings which were taken here in late November, from greenhouse plants, rooted equally well, 94 to 100 percent in 40 days, in sand, sand–peat, or sandy soil and the only benefit of treatment was to hasten rooting by about a week. April cuttings rooted 88 percent in 53 days after treatment with indolebutyric acid, 56 percent without it (16). While cuttings taken about December 1 were rooting 57 percent without treatment, there was more than 80 percent rooting of cuttings which had been treated with Rootone or Hormodin (120).

Genista. Summer cuttings of most species root well in sandy soil (7, 105). Some of them may also be taken in fall. Untreated cuttings of *G. pilosa* rooted at least 90 percent in sand when taken here in September and October, less well if taken in December.

Ginkgo biloba, maidenhair-tree. Softwood, July, cuttings root fairly readily (45). Such cuttings rooted 90 percent in sand in 36 days after treatment with indolebutyric acid (50 mg./l., 24 hr.), but untreated cuttings rooted almost as well (125).

Halesia, silverbell-tree. Cuttings of *H. carolina* and *H. monticola* which were taken here in mid-July rooted 80 percent in sandy soil in 6 weeks after treatment with indolebutyric acid (25 mg./l., 20 hr.), not more than 40 percent without treatment; and decidedly less well in sand, whether treated or not (27). Cuttings have also rooted well in sand–peat (87) and better in peat moss than in sand (66).

Hamamelis. Witch-hazels have not been easily propagated by cuttings (73, 80). Cuttings of *H. mollis* which were taken here in July rooted 59 percent in sandy soil, less well in sand, without treatment; and those which were treated with indolebutyric acid (50 mg./l., 20 hr.) rooted 73 percent in sandy soil, less well in sand.

Hedera Helix, English ivy, with the possible exception of the variety *conglomerata* (5), is easily propagated by softwood cuttings, made of growing tips (69, 83), inserted in sandy soil (80) or sand. Benefits of treatment are not great (83) but rooting is sometimes hastened (113). Optimum concentrations of indolebutyric acid are 10 mg./l., 24 hr., or 2 mg./gm. talc (61).

Helianthemum, sun-rose, is easily propagated by summer and early fall cuttings. Taken here in early October, cuttings of *H. nummularium* rooted 100 percent in sandy soil whether or not they were treated.

Helwingia japonica is not difficult to propagate by fall cuttings. Untreated cuttings rooted 90 percent in sand when taken here in early November, less well if taken in July.

Hibiscus syriacus, shrubby althaea. Softwood cuttings which were taken in July, a good month for this species (14), rooted 100 percent in 36 days after treatment with indolebutyric acid (50 mg./l., 6 hr.), 52 percent without it (83). Such cuttings are successfully made of side shoots, with a heel, and rooted in sand (105). Rooting of hardwood cuttings, which should be made of the basal or middle parts of the shoot rather than its tip, was improved by treatment (48). Such cuttings, taken from October to February, responded to treatment with indolebutyric acid 40 to 60 mg./l., 24 hr., 4 to 10 mg./cc. by the concentrated solution–dip method, or 2 to 12 mg./gm. talc (49).

Hydrangea. With the exception of *H. petiolaris* (18, 73, 113) and possibly *H. quercifolia,* the species are easy to propagate by softwood cuttings taken in summer, although those of *H. arborescens* (121) and *H. petiolaris* may root more readily if taken in spring (102). At least for *H. paniculata* (16), *H. quercifolia,* and *H. macrophylla* (87), sand–peat is a good rooting medium. Rooting of cuttings of *H. paniculata* was hastened by indolebutyric acid (20 mg./l., 24 hr. (87). July cuttings of *H. quercifolia* rooted 100 percent in sand in 39 days after treatment with Hormodin No. 2, 10 percent without it (102). Their rooting was also improved or hastened by treatment with indolebutyric acid, 1:250, in talc (104) or 30 mg./l., 10 hr. (83).

Hypericum. St. John's-worts are not difficult to propagate by summer cuttings made of tips of branches (105) and rooted in sandy soil (7). Cuttings of *H. frondosum,* treated or not, rooted 100 percent in sand in 7 weeks when taken here in early August, less well if taken in June.

Idesia polycarpa. Cuttings taken here in late July rooted 76 percent in sandy soil after treatment with indolebutyric acid (25 mg./l., 16 hr.), 40 percent without it.

Ilex cornuta. Summer cuttings root well if taken after young leaves have become dark green (110). Cuttings have also rooted well when taken as late as January (44). Rooting was hastened by treatment with a 40-unit solution of Hormodin A, 100 percent of the treated cuttings rooting in 35 days (117), or with indolebutyric acid 30 to 80 mg./l., 24 hr. (125).

Ilex crenata. Cuttings, torn from the plant at the base of the current year's growth (61), root readily if taken in fall and winter (15, 107), even

more quickly if taken in summer (125). They root well in sand (125), probably better in sand–peat (15), and respond to treatments with indolebutyric acid (20 mg./l., 24 hr., or 2 mg./gm. talc) (61). Cuttings taken here in November rooted 100 percent without treatment, in half the time with it. Cuttings taken here in January rooted 89 percent in 15 weeks without treatment, 100 percent in 6 weeks with treatment. Rooting of summer cuttings was similarly hastened by treatment (125), and treated fall cuttings developed larger root systems than the untreated (47).

Ilex glabra, inkberry. Cuttings may be taken from July or August to as late as January (15). They responded to treatments with indolebutyric acid (20 mg./l., 24 hr., or 2 mg./gm. talc) (61). Summer cuttings rooted 90 percent in sand with or without indolebutyric acid (50 mg./l., 4 hr.), but they rooted more rapidly with it (125). Rooting of summer cuttings was also hastened by treatment with 10 mg./l., 24 hr. (57).

Ilex opaca, American holly, is not difficult to propagate by late summer or fall cuttings, taken after the new growth has become dark green (76) and made with the basal cut at the base of the current year's growth, only 3 or 4 leaves nearest the tip being retained (76, 129). They may be taken as late as December (45), but August and September are better months (33). Sand (29, 101) or sand–peat (57) are good rooting media, better than sandy soil. It is well to insert cuttings at an angle, the leaves almost flat on the rooting medium (129). Treatments with indolebutyric acid (40 to 80 mg./l., 24 hr., or 12 mg./gm. talc) are beneficial (61). Cuttings taken here in late August rooted 96 percent after treatment (50 mg./l., 20 hr.), 49 percent without it. Rooting of winter cuttings was more improved by 30 or 50 mg./l. than by greater concentrations (57). October cuttings rooted 90 percent in 2 months without treatment and in 1 month after treatment (100 mg./l., 18 hr.) (125).

Ilex rugosa. Untreated cuttings taken here in November rooted 100 percent in sand–peat in 5 months. Their rooting was hastened by 2 months, but not otherwise affected, by treatment with indolebutyric acid (100 mg./l., 18 hr.).

Ilex verticillata, black-alder. Summer cuttings and those of harder wood rooted better in peat moss than in sand (14, 66). Cuttings rooted in 18 days at 80° F., much more slowly at 59° F. (126). Treatments with indolebutyric acid (40 to 80 mg./l., 24 hr., or 12 mg./gm. talc) are beneficial (61).

Ilex vomitoria, yaupon. Cuttings, untreated, rarely root, but they rooted after treatment with naphthaleneacetic acid, 1:1000, in talc (96).

Itea virginica is easily propagated by softwood cuttings. Taken here about July 1, they rooted 100 percent in sand in 4 weeks whether or not they were treated.

Jasminum nudiflorum, winter jasmine, is readily propagated by cuttings taken in late summer (80, 106) and inserted in sand (105), sand–peat (87), or sandy soil (80).

Juniperus, juniper. Cuttings respond to treatments with indolebutyric acid. Effective concentrations are 40 to 60 mg./l., 24 hr., or 5 to 12 mg./gm. talc for mountain juniper (49); 40 to 80 mg./l., 24 hr., or 12 mg./gm. talc for Chinese juniper, Pfitzer juniper, creeping juniper, savin, red cedar, *J. conferta*, and *J. excelsa* (61). Cuttings of *J. excelsa*, creeping juniper, and Pfitzer juniper root better in sand–peat than in sand (14). A few of the species are separately referred to below.

Juniperus chinensis var. *Pfitzeriana,* Pfitzer juniper. Cuttings are usually difficult to root in good percentages (103), but untreated cuttings rooted 100 percent in sandy soil in 4 months, 86 percent in sand in 11 months, when taken here in August. November cuttings have often rooted better than those taken later (13, 31, 57) but they sometimes root as well if taken in December and January (103). Rooting of cuttings taken here in December was improved by treatment with indolebutyric acid (50 mg./l., 24 hr.), 100 percent of the treated cuttings rooting in 5 months, but that treatment apparently injured August cuttings. Cuttings taken in early February rooted, in about 15 weeks, 20 percent without treatment, 92 percent with Hormodin No. 3 (103).

Juniperus communis, common juniper. Cuttings of prostrate juniper rooted about equally well when made of wood one, two, or three years old, but wood two or three years old results more quickly in larger plants (69). Cuttings of *J. communis* var. *Ashfordii* which were taken here in December rooted, without treatment, 50 percent in sand or sand–peat, 80 percent in sandy soil; and those which had been treated with indolebutyric acid (100 mg./l., 22 hr.) rooted 60 percent in sand, 90 percent in sandy soil. Taken here in December, cuttings of Irish juniper treated with indolebutyric acid (100 mg./l., 20 hr.) rooted 75 percent in sand in 6 months ,100 percent in sandy soil in 3 months; and untreated cuttings rooted as well but more slowly.

Juniperus horizontalis, creeping juniper. Untreated cuttings of Waukegon juniper rooted more than 90 percent in 8 weeks when taken here in Nomember and December. They also rooted well if taken in summer (14), but summer cuttings of the variety *plumosa* rooted less well than fall and winter cuttings (123). Fall and winter cuttings root so readily that treatments may be without much effect (57, 83) except sometimes in increasing the numbers of roots on each cutting (125). A higher concentration of indolebutyric acid is suggested for cuttings in the first stages of dormancy than for those taken in the winter (57).

Juniperus procumbens. Untreated cuttings rooted more than 90 percent in sand–peat when taken here in early November, less well if taken in February.

Juniperus Sabina, savin. Cuttings rooted better when taken in late fall or early winter than when taken later (13,31). Untreated cuttings of the variety *tamariscifolia* taken here in late November rooted 90 to 100 percent in sandy soil or sand–peat, less well in sand.

Juniperus virginiana, red cedar, and its varieties have not been easily propagated by cuttings even after treatment (17, 18, 57, 83). Cuttings of the variety *Kosteri* taken here in December failed to root without treatment, but cuttings treated with indolebutyric acid (100 mg./l., 20 hr.) rooted 58 percent in sandy soil, less well in sand.

Kalmia latifolia, mountain laurel, is considered difficult to propagate by cuttings (73, 113), but there was 100 percent rooting of untreated November cuttings in a mixture of cinders and peat, 1:1, with bottom heat at 80° F. (29). Sand–peat is also a good rooting medium (51). Rooting of late July cuttings, poor at best, was more improved by indoleacetic acid (90 mg./l., 24 hr.) than by indolebutyric acid (88). Rooting of early winter cuttings was also improved by indoleacetic acid (100 mg./l., 48 hr.); 66 percent rooting with it, 12 percent without it, in 5 months (113). Leaf-bud cuttings gave better results than ordinary stem cuttings and, taken in late July, leaf-bud cuttings rooted 80 percent in 19 weeks after treatment with indolebutyric acid (90 mg./l., 24 hr.), 20 percent without it (88).

Kalmia polifolia. Untreated cuttings rooted 100 percent in 3 months in sand–peat when taken here in mid-September, much less well when taken in mid-July.

Kerria japonica. Untreated softwood, July, cuttings rooted 100 percent in sand–peat, less well in sand (14). Treatments with indolebutyric acid (57) and indoleacetic acid did not increase percentages which rooted, but rooting was hastened by indoleacetic acid (33 mg./l.) (113).

Keteleeria Davidiana. December cuttings rooted 100 percent in 7 weeks after treatment with indolebutyric acid (100 mg./l., 24 hr.), not at all meanwhile without treatment (109).

Kolkwitzia amabilis, beauty-bush. Softwood, summer, cuttings, made of the tips of shoots (48) usually root well in sand (105) or sandy soil (80). Rooting of June or July cuttings was hastened by treatment with indolebutyric acid 12 mg./gm. talc or 20 mg./l., 24 hr. (49), or 60 mg./l., 4 hr. Cuttings given the last named treatment rooted 100 percent in 34 days (125).

Laburnum anagyroides, golden-chain. Softwood, July cuttings, made with the basal cut at a node, rooted 100 percent without treatment (14).

Larix sibirica, Siberian larch. There was some rooting of softwood, early summer, cuttings treated with indoleacetic acid (50 mg./l., 24 hr.), not of the untreated; but cuttings of slightly harder wood, taken two weeks later, failed to root whether or not they were treated (65).

Lavandula officinalis, lavender. Summer cuttings, untreated, root readily in sandy soil (80, 105).

Lespedeza. Cuttings of *L. Thunbergii* taken here in early October rooted 66 percent in sandy soil after treatment with indoleacetic acid (100 mg./l., 18 hr.), not at all without it. The species is also propagated by cuttings taken in summer and rooted in sandy soil (80).

Leucothoe Catesbaei is easily propagated by softwood cuttings (67), made with the basal cut a half inch below a node (14). July cuttings rooted 100 percent in sand–peat in 12 weeks without treatment or in 10 weeks after treatment with indolebutyric acid (10 mg./l., 24 hr.) (88). This species is also readily propagated by leaf-bud cuttings which, taken in late June, rooted 100 percent in 10 weeks without treatment (90).

Libocedrus decurrens, incense cedar. Untreated cuttings taken here in November remained alive but unrooted in sand–peat for 15 months. Some of them were then treated with indolebutyric acid and all were replanted. Those treated with 150 mg./l., 24 hr., rooted 100 percent in the next 9 weeks. Results were a little less good with 75 mg./l. and only 50 percent of the untreated rooted in a total of 22 months.

Ligustrum. Privets can be propagated by softwood, summer, cuttings in sand or by hardwood, fall, winter, or early spring cuttings. Early summer cuttings of Japanese privet rooted best if made of growing tips, not older wood (125). There are sometimes more roots per cutting or more rapid rooting following treatments with indolebutyric acid (57, 83, 117), optimum concentrations for California privet being 80 mg./l., 24 hr., or 12 mg./gm. talc (61). For privets in general, naphthaleneacetic acid is more effective (49). Concentrations of 60 mg./l., 24 hr., or 1:250 in talc hastened rooting of September cuttings of *L. compactum* (96).

Lindera Benzoin, spice bush, is sometimes propagated by summer cuttings

made of half-ripe young shoots (80), but they do not ordinarily root very well (51).

Liquidambar. Cuttings of *L. formosana, L. orientalis* (105), and sweet gum (42) will root in sand if taken in summer and made of half-ripened wood with a heel.

Liriodendron Tulipifera, tulip-tree. Propagation by cuttings has been considered impractical (105), but there was 52 percent rooting of untreated July cuttings made with the basal cut a half inch below a node (14). Rooting of summer cuttings, in sand–peat, was hastened by treatment with indoleacetic acid in a relatively high concentration (87).

Lonicera, honeysuckle. Softwood, summer, cuttings of many species root well in sand (44, 105) or sandy soil (7), and hardwood cuttings are also used with good results. Untreated hardwood cuttings of *L. Morrowii* rooted well when taken in April (13). Cuttings of *L. pileata* and *L. nitida,* without treatment, rooted 100 percent in sandy soil in about 8 weeks when taken here in December. Hardwood, early spring, cuttings of *L. coerulea* (65) and Tatarian honeysuckle (40, 65) responded to treatment with indoleacetic acid 50 mg./l., 48 hours for the former, 24 hours for the latter. Rooting of November cuttings of *L. Korolkowii* was more improved by that acid (100 mg./l., 24 hr.) than by indolebutyric acid (83) but very dilute solutions of the latter are effective with softwood cuttings. July cuttings of *L. nitida* rooted 100 percent in 14 days after treatment with indolebutyric acid 5 mg./l., 24 hr. (57) and that treatment was followed by good rooting of softwood, spring, cuttings of *L. Maackii* in 16 days (48). July cuttings of *L. fragrantissima* rooted so well without treatment that treatments were of no significant advantage (104), but the rooting of June cuttings of that species was hastened by indolebutyric acid (10 mg./l., 24 hr.) (57).

Lycium, box-thorn. Untreated softwood, summer, cuttings of Chinese matrimony-vine and *L. ruthenicum* root readily (42). Hardwood cuttings also root well. Taken here in late March, buried in sand in a cold cellar for 3 weeks and then planted in the field, cuttings of *L. ruthenicum* rooted 100 percent in 9 weeks with or without treatment.

Maclura pomifera, osage orange, can be propagated by softwood cuttings, the basal cut a half inch below a node (14). July cuttings rooted 100 percent in sand–peat in 42 days after treatment with indoleacetic acid (100 mg./l., 24 hr.), 32 percent without treatment (87).

Magnolia. These have not been considered easy to propagate by cuttings (73). Cuttings are made of soft wood, taken in summer (63, 67, 105, 124). Sand is a good rooting medium (63, 87, 105)—better, at least for some species, than sand–peat (14) and better, at least for *M. Soulangeana* (27), than sandy soil. A small heel is considered desirable (63). Untreated cuttings may root slowly (124) or not in large percentages and treatments are worth while. Cuttings of *M. Soulangeana* which were taken here in late June rooted 100 percent in 35 days after treatment with indolebutyric acid (50 mg./l., 22 hr.), 32 percent without it. This treatment also improved the rooting of early July cuttings of *M. stellata.* August cuttings of *M. liliflora* rooted 100 percent in 49 days after that treatment, 21 percent without it, and rooting of June cuttings of *M. Kobus* was improved by similar treatment with 80 mg./l. (125).

Malus, apple. Softwood cuttings of some species and varieties will root if they are taken in late spring or early summer and if they are more than usually well protected against wilting (42). Taken here in late June, cuttings of *M. atrosanguinea* rooted 57 percent in sand–peat without treatment; and cut-

tings of *M. arnoldiana* rooted 60 percent after treatment with indolebutyric acid (50 mg./l., 20 hr.), although not at all without treatment. Early July cuttings of *M. pumila* var. *Eleyi* (the common apple is *M. pumila*) rooted 70 percent in sand after treatment with indolebutyric acid (50 mg./l., 4 hr.), not at all without it (125). Cuttings of another variety rooted well after treatment with naphthaleneacetic acid (20 mg./l., 24 hr.) if they were taken in spring or early summer before growth had been completed (81). There was no rooting of similar cuttings of Siberian crab whether or not they were treated (113).

Hardwood cuttings of some varieties of the common apple, made of wood in its first, second, or third year (126) will root, but propagation in this way has not in the past proved commercially practical (12). Cuttings of Northern Spy taken in March rooted 25 percent in peat moss at 65° F., not at all in sand–peat or sand (66). Similar cuttings of Delicious failed to root even after treatment (95). There was 75 to 100 percent rooting of hardwood (November to February) cuttings of Rhode Island Greening and Grimes Golden which were made of tips of the current year's growth, treated with indolebutyric acid (40 mg./l., 24 hr.), and immediately buried in moist peat moss, but no rooting of untreated cuttings (48, 49). Attempts to repeat this with cuttings of McIntosh taken here in February and March were unsuccessful. Best rooting, only 20 percent, was of treated cuttings made of wood two years old or of tips of the newest growth, but the rooted cuttings died when transplanted.

Myrica Gale, sweet gale, is easily propagated by softwood cuttings. Untreated cuttings which were taken here in late June rooted 85 percent in sand in 57 days. July cuttings rooted 100 percent in sand–peat in 38 days after treatment with indoleacetic acid (100 mg./l., 24 hr.), 60 percent without it (87).

Osmanthus ilicifolius. Summer cuttings root readily in sand (105) or sandy soil (80). Rooting was hastened by treatment with indoleacetic acid (20 mg./l., 24 hr.) (113) or indolebutyric acid (150 mg./l., 4 hr.), but untreated cuttings taken in late July rooted more than 90 percent (125).

Oxydendrum arboreum, sorrel-tree, can be propagated by softwood cuttings, short side shoots with a heel (80). Late July cuttings rooted 80 percent in sand–peat in 8 weeks after treatment with indolebutyric acid (90 mg./l., 8 hr.), less well in sand, and not at all in 8 weeks without treatment (88).

Pachistima. Cuttings of *P. Canbyi* and *P. Myrsinites* taken here in October and November rooted more than 90 percent in sand–peat whether or not they were treated. Softwood cuttings are also successfully taken in July and rooted in sand (67).

Pachysandra terminalis is easily propagated by July and August cuttings (106). Late June cuttings rooted 100 percent in 28 days after treatment with indolebutyric acid (30 mg./l., 6 hr.), 60 percent without it (83). Concentrations effective with winter cuttings are naphthaleneacetic acid 20 to 100 mg./l., 24 hr., (47) and indolebutyric acid 20 to 40 mg./l., 24 hr. or 5 to 12 mg./gm. talc (49).

Parrotia persica. Summer cuttings rooted 100 percent in sand–peat in 38 days after treatment with indoleacetic acid (100 mg./l., 24 hr.), less than 50 percent without it (87).

Parthenocissus. Boston ivy and Virginia creeper are easily propagated by softwood cuttings. Untreated August cuttings of the former rooted 90 percent in 20 days and treated cuttings rooted no better (16).

Passiflora racemosa, passion-flower. Softwood cuttings taken here in July rooted 90 percent in sand in 8 weeks after treatment with indolebutyric acid (50 mg./l., 24 hr.), 40 percent if untreated. Sandy soil may also be used as a rooting medium (80).

Periploca. Softwood cuttings of silk-vine and *P. sepium* taken here in early August rooted 100 percent in sand–peat in 4 weeks with or without treatment. Late August cuttings of silk-vine, in sand, failed to root in 4 weeks without treatment but rooted 70 percent after powder–dip treatment with indolebutyric acid, 1:500 (104).

Philadelphus, mock-orange. Softwood, July, cuttings of many species root well without treatment (44, 66, 116, 125); better sometimes in sand–peat that in sand (14, 66). The only response of *P. grandiflorus* to treatment was more roots on each cutting (125). Rooting of cuttings of *P. cymosus* (125) and *P. coronarius* (83) was hastened by treatment with indolebutyric acid, the former responding to 30 to 80 mg./l., 4 hr., and the latter to 50 mg./l., 20 hr.

Photinia. The species can be propagated by fall or late summer cuttings, short side-shoots, with a heel (105). Fall cuttngs of *P. glabra* rooted 100 percent in 62 days after treatment with indolebutyric acid (50 mg./l., 18 hr.), 5 percent without it (20). Summer cuttings of *P. serrulata* rooted 20 percent without treatment, 80 percent after treatment with indolebutyric acid (20 mg./l., 6 hr.) (119).

Physocarpus opulifolius, ninebark, is easily propagated by softwood, summer cuttings. They rooted better in sand–peat than in sand, better at 60° F. than at 70° F. (116). Cuttings of harder wood are also successfully used. Taken in November, they rooted 80 percent in 53 days without treatment and only a little better after treatment with indolebutyric acid (50 mg./l., 40 hr.) (16).

Picea Abies, Norway spruce. Cuttings rooted better if taken in November than if taken in late winter (38), better if taken in December than if taken in spring, summer, fall, or later in the winter (24). Best results have followed the taking of cuttings, laterals rather than terminals (109), from the lower in preference to the upper part of trees (35). Cuttings root with less difficulty than do those of most spruces (106); and cuttings of the varieties *nigra, Maxwellii, Clanbrasiliana,* and *Ohlendorfii* which were taken here in December rooted at least 70 percent without treatment, no better and not always so well with it. Treatments for 24 hours with solutions of indoleacetic (41) or indolebutyric acid (24) failed to improve rooting significantly and similar treatment with water alone was apparently somewhat injurious (24). Powder–dip treatment with indolebutyric acid (4 mg./gm. talc) caused some injury in many cases (24), but rooting was somewhat improved by indoleacetic acid in talc (41). November cuttings, made with the basal cut somewhat above the base of the current year's growth and planted immediately in a mixture of equal parts of sand and peat humus in shaded outdoor frames, rooted about 50 percent without treatment, 82 percent in 10 months after treatment with indoleacetic acid (5mg./gm. talc) (39). Treated cuttings in that experiment rooted less well in sand, but untreated cuttings from trees 40 years old, made with the basal cut not far above the base of the current year's wood, rooted 80 percent in sand; better, with less rotting, in open benches in a warm greenhouse than in a closed sweat bench (24).

Picea glauca var. *conica.* Taken here in early December, cuttings in sand–peat rooted 39 percent without treatment, 92 percent after treatment with indolebutyric acid (70 mg./l., 20 hr.), with results less good in sand. Late winter cuttings respond to treatment with 40 to 60 mg./l., 24 hr., or 2 to 12 mg./gm. talc, or, by the concentrated solution–dip method, 4 mg./cc. (49). Cuttings are taken in summer in England (7).

Picea Omorika, Serbian spruce. Suggested treatments with indolebutyric acid are 40 to 80 mg./l., 24 hr., or 12 mg./gm. talc (61).

Picea pungens, Colorado spruce. Best rooting was of cuttings taken in February (61, 67, 127). Summer proved to be a poor time to take them (126). April cuttings rooted 80 percent in 8 weeks after treatment with indoleacetic acid (100 mg/l., 24 hr.), but bud development was retarded for a few months following (109). Indolebutyric acid (40 to 80 mg./l., 24 hr., or 12 mg./gm. talc) may also be used (61). Cuttings rooted better in peat moss than in sand (44), but cuttings of the variety *Kosteriana* rooted well in sand (66).

Picea sitchensis, Sitka spruce. Late winter cuttings made of the current year's wood rooted 100 percent in sand–peat in 60 days after treatment with indolebutyric acid (25 mg./l., 24 hr.), less well if taken in fall or early winter or if not treated (43).

Pieris. P. japonica and *P. floribunda* can be propagated by cuttings taken in July or August when the wood is nearly ripe, made with the basal cut about one-fourth inch below a node (67), and inserted in sand–peat (80, 88). July cuttings of *P. japonica* rooted 80 percent without treatment, 100 percent in 6 weeks with treatment (88). Indolebutyric acid (10 mg./l., 24 hr.) has given good results with that species (61), which is also easily propagated by leaf-bud cuttings taken in early summer (89).

Pinus Strobus, white pine. Cuttings, treated or not (61), have not often rooted well if obtained from mature trees or, in fact, from trees more than three or four years old (24, 42, 109), but cuttings from older trees can be rooted (24, 28, 74, 94). Cuttings which were taken here in mid-March from a tree about thirty years old did not root without treatment and rooted poorly or not at all, with or without treatment, if taken from the upper part of the tree; but cuttings from the lower part of the tree rooted 70 percent in sand–peat in 3 months after treatment with indolebutyric acid (200 mg./l., 5 hr.) (28).

Deuber (24) got 14 and 16 percent rooting of cuttings taken in December and January from trees thirty years old, 30 percent rooting of cuttings taken in February from a tree sixty years old; such cuttings rooting better in sand than in sand–peat (1:1), better in the moist air of a greenhouse at 70° F. than in a sweat bench at higher temperatures. Rooting was somewhat improved by treatment for 24 hours with indolebutyric acid (100 mg./l.), but improvement was not very great and this treatment was sometimes injurious. He found that small cuttings, lateral twigs, root better than large cuttings, terminal shoots, with all taken from the lower part of the tree, and that winter, especially late winter, is apparently a better time to take cuttings than spring, summer, or fall.

Snow (94) took cuttings in August from trees ten years old and planted them in outdoor beds, covered with sash at night, in a six-inch layer of sand–peat over old horse manure. They were there carried through the winter mulched with hay, rooting the following summer. There was 35 percent rooting of those which had been treated only with water, 47.5 percent rooting of those which had been treated with indolebutyric acid

(25 mg./l., 6 hr.) followed by treatment with a dust containing indolebutyric acid or naphthaleneacetic acid, but no benefit from the solution treatment alone. Best rooting was of cuttings farthest from the terminal, cuttings taken from lateral branches of lateral branches in the lower part of the tree.

Rooting of cuttings from very young trees, better in sand–peat than in sand, was improved by treatment with indoleacetic acid (200 mg./l., 24 hr.) (109).

Deuber got about 50 percent rooting of cuttings of lace-bark pine from a tree ten years old and he mentions the rooting of cuttings of Scots pine, Austrian pine, and a few other species by other investigators. In the present limited state of our knowledge, propagators working with these and other pines will probably do well to take cuttings, laterals not terminals, from the lower part of the trees in late winter. Cuttings of lace-bark pine, a variety of mountain pine (61), and white pine have sometimes rooted better after treatment with indolebutyric acid; and this chemical, if used, should probably be applied to dormant cuttings in a relatively concentrated solution for a relatively short time.

Poncirus trifoliata. Cuttings which were taken here in mid-December and inserted in sand–peat rooted 60 percent in 9 weeks after treatment with naphthaleneacetic acid (100 mg./l., 17 hr.). Untreated cuttings and those similarly treated with indolebutyric acid were alive but not rooted at the end of that time.

Populus, poplar. Hardwood, April, cuttings of white poplar and black poplar rooted poorly without treatment, very well after treatment with indoleacetic acid (50 mg./l., 30 hr. or 100 mg./l., 18 hr.) (65). Rooting of October cuttings of quaking aspen and March cuttings of large-toothed aspen was much improved by treatment, the former with indoleacetic acid (100 mg./l., 24 hr.) (109), the latter with indolebutyric acid (10 mg./l., 27 hr.) (91). Late November cuttings of cottonwood, untreated, rooted well when buried in a cold pit for about two months before being planted (52). Treated hardwood cuttings of quaking aspen rooted better in sand than in sand–peat (91). Rooting of softwood, July or early August, cuttings of white poplar and of a hybrid was much improved by treatment; indoleacetic acid (50 mg./l., 24 hr.) being effective with the former (65) and indolebutyric acid (20 mg./l., 12 hr.) with the latter (1).

Potentilla fruticosa is easily propagated by softwood cuttings. Taken here in early July, they rooted 100 percent in sand in 3 weeks whether or not they were treated.

Prunus spp. The best time to take softwood cuttings is, generally speaking, in late spring and early summer. Treated cuttings of three plums and a cherry rooted best if taken immediately after growth had stopped (81); similar cuttings of another cherry, if made of tips of shoots taken shortly before they became woody (11). Indolebutyric acid (15 or 20 mg./l., 24 hr.) markedly improved the rooting of such cuttings of both plum and cherry (81). Cuttings of a species of Prunus taken in mid-July rooted 90 percent in 38 days after treatment with naphthylacetamide (1:1000, in powder), 5 percent without treatment (104). A few other species are discussed separately below.

Prunus cerasifera, cherry plum. Softwood cuttings, made in spring of terminal shoots which were still growing, rooted 100 percent in 4 weeks

after treatment with naphthaleneacetic acid (30 mg./l., 12 hr.), the most effective root-inducing substance for this species, 20 percent without it (82). Similar cuttings responded to indolebutyric acid (2 to 5 mg./gm. talc, or, by the concentrated solution–dip method, 4 mg./cc.) (49).

Prunus glandulosa, dwarf flowering almond, is not difficult to propagate by untreated softwood, July, cuttings (14, 44), made with the basal cut at the base of the current season's wood (46) and planted in sand–peat (14).

Prunus incisa can be propagated by softwood cuttings taken with a heel early in the season or when the new shoots are about three inches long (105). Rooting of late summer cuttings was improved by naphthaleneacetic acid (25 mg./l., 24 hr.) (113).

Prunus japonica. Late June cuttings, untreated, rooted about 50 percent when made of tips, not basal parts, of young shoots (70).

Prunus Laurocerasus, cherry laurel, is easily propagated by late summer cuttings (7). Untreated cuttings taken here in early August rooted more than 90 percent in sand–peat in seven weeks. January cuttings rooted 80 percent in 34 days after treatment with indolebutyric acid (40 mg./l., 6 hr.), not at all without treatment (119).

Prunus maritima, beach plum. Softwood cuttings taken here in late June failed to root without treatment. They rooted 43 percent in sandy soil after treatment with indolebutyric acid (12.5 or 25 mg./l., 20 hr.), less well in sand or sand–peat or if cuttings were taken later.

Prunus Padus, European bird cherry. July cuttings rooted 32 percent without treatment, 52 percent after treatment for 20 hours with a solution of Auxilin containing indolebutyric acid 22 mg./l. (69).

Prunus pseudocerasus. Softwood cuttings, made of entire young shoots, are successfully taken when such shoots are about three inches long (105).

Prunus subhirtella, Higan cherry. Softwood cuttings have been taken with some success in early June (55). Taken here near the last of that month, they did not root if untreated, but rooted 50 percent in sand–peat in 4 weeks after treatment with indolebutyric acid (25 mg./l., 20 hr.).

Prunus tomentosa. Hardwood cuttings rarely root but softwood cuttings root fairly well (127) in sand–peat or sandy soil. Untreated cuttings rooted 63 percent in sand, 80 percent in sandy soil when taken here in late May, less well if taken a month later. Rooting is better if most of the leaves are left on the cuttings (126). Taken here in mid-June, cuttings rooted 100 percent in sand–peat in 3 weeks after treatment with indolebutyric acid (40 mg./l., 6 hr.), 35 percent in 7 weeks without treatment.

Prunus triloba, flowering almond. Cuttings root best if made of new shoots taken in spring (128) or when they are about three inches long (105). Rooting of July cuttings of the variety *plena* was improved by treatment with indolebutyric acid (50 mg./l., 4 hr.) (125).

Pseudotsuga taxifolia, Douglas-fir. Late winter cuttings rooted 80 percent in sand–peat after treatment with indolebutyric acid (50 mg./l., 24 hr.), less well without treatment or when taken in fall and early winter (43).

Pterocarya, wing-nut. The species, or some of them, can be propagated by late-summer cuttings made of young shoots with a heel (80). Cuttings of *P. stenoptera* rooted 90 percent in 3 weeks after treatment with Hormodin A (20 B T I units), not at all meanwhile without treatment (118).

Pueraria Thunbergiana, kudzu-vine. Cuttings are decidedly responsive to treatments with potassium permanganate. Those treated 30 minutes with

a solution of 1 ounce in 8 gallons water rooted 86 percent in 30 days, which was much better than the rooting of untreated cuttings or of those treated with some ordinary root-inducing substances (75).

Pyracantha, firethorn. Cuttings are taken in summer (67) or fall (124). Untreated cuttings of *P. coccinca* taken here in early August rooted 100 per- in sand–peat and in sand. October (98, 125) and November (83) cuttings have also rooted well. Rooting is better if thorns are removed (42) and if the basal cut is at a node (14). Indolebutyric acid hastened rooting (125), but indoleacetic acid (50 mg./l., 24 hr.) was more effective (83) and also improved rooting of cuttings of *P. atlantioides* (72). September cuttings of *P. crenulata* rooted, in 35 days, 6 percent without treatment, 75 to 100 percent after treatment with indoleacetic acid (25 mg./l., 20 hr.), a treatment which was of more benefit to cuttings of *P. coccinea* made of tips of shoots rather than their basal parts (68). December cuttings of *P. coccinea* rooted 82 percent without treatment, 100 percent with Hormodin No. 1 (102).

Pyrus, pear. Hardwood cuttings of most varieties of common pear are not easily rooted, but some can be propagated by treated softwood cuttings. Untreated cuttings did not root but those treated with naphthaleneacetic acid (40 mg./l., 12 hr.) rooted 100 percent if made of growing shoots in spring, 75 percent if taken in early summer when growth had recently ceased (82). There was also good rooting of cuttings taken in spring or early summer and treated with indolebutyric acid (20 to 40 mg./l., 24 hr.) (81); and 2 mg./gm. talc improved the rooting of early June cuttings of sand pear (49). Cuttings of Hood, an oriental pear, rooted 100 percent in sand–peat in three weeks after treatment for 24 hours with Hormodin A (40 B T I units), not at all without treatment (117).

Quercus, oak. Cuttings from other than very young trees are not likely to root much without treatment. Untreated July cuttings of English oak did not root, but there was 56 percent rooting of cuttings from trees 6 to 8 years old which had been treated with indoleacetic acid (50 mg./l., 18 hr.), 34 percent rooting of cuttings from a tree 20 years old similarly treated with 200 mg./l. (65). Cuttings of red oak from mature trees failed to root, but there was 82 percent rooting of February cuttings made from the basal parts (wood more than one year old) of 4-year-old trees which had been treated with indoleacetic acid (400 mg./l., 24 hr.), 22 percent rooting of untreated cuttings (109).

Rhododendron. As may be seen by reference to the table, early summer cuttings of some species root well without treatment. That is true also of cuttings of *R. japonicum, R. racemosum* (88), *R. lactevirens* (90), *R. lapponicum* (105), *R. yunnanense,* and *R. indicum* (106). Cuttings of most azaleas (9), *R. maximum* (5), and the common evergreen hybrids have been more difficult to root although cuttings of some, e. g., the varieties *Boule de Neige, catawbiense album,* and *purpureum elegans,* rooted well without treatment (77).

Cuttings of many species root better or more rapidly after treatment with indolebutyric acid, some effective concentrations of which are listed in the table. For broad-leaved evergreen species and hybrids, a relatively high concentration of indolebutyric acid (40 to 80 mg./l., 24 hr., or 12 mg./gm. talc (61) or 10 to 20 mg./cc. by the concentrated solution–dip method (49)) is usually needed. Cuttings of the hybrid *album grandiflorum* taken here in late August rooted 62 percent in 5 months without treatment, 92 percent in 3 months after treatment with 50 mg./l., 20 hr.

ROOTING OF CUTTINGS OF RHODODENDRON

Species and Time of Taking Cuttings	Indolebutyric Acid Treatment	Rooted with Treatment		Rooted without Treatment		Lit. Cit.
		Percent	*Days*	*Percent*	*Days*	
R. arborescens						
Late June	80 mg./l., 4 hr.	70	63	Same, but better roots		125
Late May	12 mg./gm. *	100	45	25	45	61
Mid-July	5 mg./gm. *	100	33	0	33	61
R. calendulaceum						
Late May	12 mg./gm. *	75	54	25	54	61
Early July	50 mg./l., 16 hr.	100	80	50	80	**
R. canadense						
Early July	50 mg./l., 20 hr.	75	50	27	80	**
R. canescens						
Late June	12 mg./gm. *	75	92	0	92	61
	Hormodin A	100	42	30	42	118
R. Collettianum						
Late June	12 mg./gm. *	50	61	0	61	61
R. dauricum						
Mid-July	5 mg./gm. *	100	53	25	53	61
R. gandavense						
Late June	60 mg./l., 8 hr.	100	70	80	105	90
R. gandavense (hybrids)						
Early June	12 mg./gm. *	75	47	0	47	61
R. hursutum						
Mid-August	30 mg./l., 24 hr.	90	80	90	96	**
R. micranthum						
Late July	10 mg./l., 8 hr.	100	91	60	91	88
R. minus						
Late November	75 mg./l., 16 hr.	50	150	0	150	**
R. mixtum						
Late June	90 mg./l., 10 hr.	80	147	20	147	88
R. molle						
Mid-July	2 mg./gm. *	50	68	0	68	61
R. mucronatum						
Late May	2 mg./gm. *	100	33	100	33	61
Mid-June	30 mg./l., 4 hr.	70	73	10	73	125
R. mucronulatum						
Early July	50 mg./l., 18 hr.	100	87	74	110	**
Late June	12 mg./gm.. *	75	46	0	46	61
R. nudiflorum						
Late June	80 mg./l., 4 hr.	73	62	56	62	125
R. obtusum (varieties)						
Early June	70 mg./l., 20 hr.	93	49	86	63	90
Late June	2 mg./gm. *	100	37	25-75	37	61
	Hormodin A	100	49	56	49	117
R. obtusum var. *japonicum*						
Late June	2 mg./gm. *	100	34	100	34	61
R. obtusum var. *Kaempferi*						
Early July	50 mg./l., 4 hr.	85	45	85	80	125
R. ponticum						
Late June	40 mg./l., 24 hr.	80	63	80	112	88
R. pulchrum						
Late July	90 mg./l., 24 hr.	100	35	100	50	88
R. reticulatum						
Late July	40 mg./l., 8 hr.	100	35	100	56	88
R. roseum						
Mid-July	12 mg./gm. *	50	68	0	68	61
R. Schlippenbachii						
Late May	12 mg./gm. *	75	76	0	76	61
R. Vaseyi						
Late June	2 mg./gm. *	75	76	0	76	61
Late June	10 mg./l., 8 hr.	60	105	30	105	88
R. viscosepalum						
Late July	25 mg./l., 6 hr.	100	52	60	90	**
R. viscosum						
Early June	15 mg./gm. *	50	47	0	47	61
Late July	90 mg./l., 4 hr.	100		100 (but more slowly)		88
R. yedoense var. *poukhanense*						
Mid-July	2 mg./gm. *	100	22	25	22	61
Late July	50 mg./l., 20 hr.	100	64	12	60	**

* In talc. ** Work done here.

Cuttings of *Rhododendron mucronatum, R. pulchrum, R. obtusum,* and *R. yedoense* var. *poukhanense* will root at almost any time (9), but cuttings of most azaleas, deciduous species, root best if taken in spring or early summer when the wood is soft (90, 125), much less well in fall or winter (61). Best rooting of cuttings of *R. calendulaceum, R. mucronulatum, R. viscosepalum,* and *R. canadense* followed when they were taken here before rather than after the middle of July.

A good time to take cuttings of broad-leaved evergreen Rhododendrons, including the named hybrids, is August (9, 77) or after the leaves on the newest growth have become dark green. They have also rooted well when taken in September, October, or early November (61, 77). Such cuttings are made of terminal shoots, without flower buds, cut through the basal ring (61). Nearing and Connors (77), using different methods, successfully shorten cuttings to three inches below the lowest of the three to five leaves which are left on the cutting.

The basal cut may be made in wood of the current year in the case of Indian and Kurume azaleas (9), but cuttings of other azaleas are usually made with a heel (9, 61) or with the basal cut at the juncture of the wood of the current and previous year (105).

A mixture of sand and peat, 1:1 or 3:2, is a good rooting medium (9, 90), better than sand (44, 88) and better than a mixture (2:1:1) of sand, peat, and loam. Azalea cuttings rooted better in sand–peat which had been previously used than in a freshly prepared mixture (44). Bottom heat may benefit fall cuttings but is unnecessary for those taken in July and August (9).

Broad-leaved evergreen Rhododendrons can also be propagated, beginning in July or when new leaves have fully developed, by leaf-bud cuttings consisting of one leaf of the current year's growth, its axillary bud, and an attached bit of bark and wood or piece of stem about a half inch long (61, 88). This leaf-mallet type of cutting, so set as not to cover any of the blade of the leaf with rooting medium, rooted in higher percentages than stem, terminal cuttings (61). Such cuttings, in sand–peat at 70 to 75° F., rooted in 13 weeks without treatment or in 10 weeks after treatment of the mallet or heel with indolebutyric acid (60 mg./l., 8 to 24 hr.) (89). Leaf-bud cuttings of the variety *purpureum elegans* rooted 100 percent in 15 weeks with treatment (indolebutyric acid 120 mg./l., 20 hr.), 88 percent in 18 weeks without it (90).

Rhodotypos scandens. Softwood, late spring, cuttings root well. Taken here in late May, they rooted 86 percent in sand in 8 weeks without treatment, 100 percent in 3 weeks after treatment with indolebutyric acid (25 mg./l., 24 hr.). Late June cuttings rooted 84 percent in 7 weeks after treatment with indolebutyric acid (1:1000, in talc), not at all meanwhile without treatment (104).

Rhus, sumac. Untreated July cuttings of fragrant sumac rooted 80 to 100 percent in sand–peat, less well in sand (66). Cuttings of staghorn sumac and smoke-tree (*Cotinus Coggygria* or *Rhus Cotinus*) are taken in England (80) in late summer, but smoke-tree is not readily propagated by cuttings (73).

Ribes. Garden currant can be propagated by September or October cuttings set in the field, the upper bud level with the soil surface, and given a protective mulch in winter (121). That and other species can also be propagated by summer cuttings. July cuttings of European black currant, alpine currant (44), and northern red currant (65) rooted well. Gooseberry cuttings may root less readily (5, 105), but untreated cuttings

of the variety Poorman which were taken here in mid-July rooted 70 percent in sandy soil, 32 percent in sand. Late June cuttings of alpine currant rooted 77 percent in 22 days after treatment with indolebutyric acid (20 mg./l., 24 hr.), 39 percent without it (57). Rooting of October cuttings of *R. Grossularia* was improved by treatment with naphthalene-acetic acid (50 mg./l., 24 hr.) (113).

Robinia Pseudoacacia, black locust, and its varieties can be propagated by hardwood, winter and early spring, cuttings treated with indoleacetic acid or naphthaleneacetic acid (100 mg./l., 24 hr.). Cuttings, six to twelve inches long and about one half inch in diameter, were allowed to callus for seven to ten days in moist sphagnum moss at 68° to 80° F. before treatment. Stored in moist sand at 70° F. for about ten days following the treatment, they rooted, in soil, more than 60 percent in the field, more than 90 percent in a greenhouse (99).

Rosa, rose. Most hardy climbing roses and hybrids of *R. rugosa,* some hybrid teas, and some hybrid perpetuals do well on their own roots (121, 122). Cuttings of some species are difficult to root (10), but hybrid perpetuals, Polyantha roses, most hardy climbers, and some hybrid teas can be propagated by dormant, late fall or winter, cuttings planted immediately in a cold frame or stored cool, in sand, during winter and planted outside in spring (122). Rose cuttings are taken in late fall in England, and untreated October cuttings of *R. rugosa* there rooted to the extent of 100 percent (10).

Greenhouse varieties of hybrid teas were most responsive to treatment if cuttings were taken from canes of flowering wood just after petals began to fall, and softwood cuttings rooted best if taken from garden varieties of hybrid teas in August or from climbers and creepers in July and August (62). Three buds are enough on a cutting (122). Summer cuttings of *R. Hugonis, R. omeiensis,* and prairie rose rooted better if made with a heel (46) but all roses do not need one (121). There was good rooting of three-node cuttings of hybrid teas made from the basal portion of flowering shoots, the basal cut in the internode below a node, the lowest leaf and the terminal leaflets of the remaining leaves removed (62). Sand–peat, sand (62), and sandy soil (121, 122) have been used successfully as rooting media. Sandy soil gave better results than sand with treated cuttings of a hybrid perpetual (27).

Indolebutyric acid in very low concentrations (48) is the most effective of the known root-inducing substances for rose cuttings and some of the results of work with it as described by Kirkpatrick (62) are here summarized. Cuttings of several, not all, garden varieties of hybrid teas, taken in August from flowering shoots, rooted as much as 50 percent more after treatment with 2.5 mg./l., 24 hr., or 2 mg./gm. talc. Similar cuttings of greenhouse varieties rooted in 15 to 20 days after treatment with 1.25 to 2.5 mg./l., 24 hr., or 1 to 2 mg./gm. talc. Rooting of summer cuttings of several climbers and creepers, also *R. multiflora,* was improved by 5 mg./l., 24 hr., or 2 mg./gm. talc but at least twice these concentrations were needed to induce rooting of cuttings of *R. Hugonis.* Treatments did not affect rooting of Pernettiana hybrids. Dormant cuttings of *R. multiflora* responded to 5 to 10 mg./l., 24 hr., or 2 mg./gm. talc if treated cuttings were then given a temperature of 65° to 75° F., not lower. Air temperatures of from 60° to 80° F. proved to be best for quick rooting of rose cuttings in general and it was necessary to give them heat at other times but not in summer. Indolebutyric acid had little effect at temperatures of less than 60° F.

Rubus. Cuttings of Van Fleet raspberry, new shoots taken in May, rooted well in 26 days (127), but some red raspberries are not readily propagated in this way (115). Leaf-bud cuttings of a black raspberry taken in July, made to include an axillary bud and a heel of bark and wood, rooted 100 percent in sand (100). This method is successful with some red raspberries, not with others (115). Leaf-bud cuttings of several species, taken in July or August before leaves began to mature, rooted in sand in 2 weeks or in half the time required for stem cuttings (112).

Salix, willow. Softwood, summer, cuttings of white willow (44), dwarf willow (105), *S. Elaeagnos* (66), and other species root readily in sand. Rooting of late June cuttings of *S. Elaeagnos* and early July cuttings of pussy willow was, however, at least hastened by indolebutyric acid, 10 mg./l., 6 hr., for the former (83); 5 mg./l., 24 hr., for the latter (57).

Salvia officinalis, garden sage. Untreated cuttings taken here in October rooted 100 percent in sandy soil in 6 weeks. Taken here in late June, they rooted, in sand, 79 percent in 7 weeks without treatment, 100 percent in 3 weeks after treatment with indolebutyric acid (40 mg./l., 24 hr.).

Sambucus, elder. Softwood, summer, cuttings of American elder (44), European elder (66), European red elder, and *S. melanocarpa* (116) root well. Cuttings of American elder, whole new shoots about five inches long, root well if taken in spring (127) and that is a good time to take cuttings of the varieties also (51). Sand is a good rooting medium (66, 127), better, at least for some species, than sand–peat (116).

Sciadopitys verticillata, umbrella-pine. January cuttings four or five inches long, from trees about seven years old, were treated with indolebutyric acid (20 mg./l., 20 hr.), planted in a mixture of sifted cinders three parts and peat moss one part, and transplanted after three months to sand–peat where they rooted 70 percent in 8 months (23). There was no rooting meanwhile of untreated cuttings.

Securinega suffruticosa. Hardwood cuttings taken here in late March, buried in sand at about 50° F. for one month and then planted in soil outdoors, rooted 100 percent in 6 weeks whether or not they were treated.

Sorbaria sorbifolia. Untreated softwood, summer, cuttings, made with the basal cut at a node, rooted 80 percent in sand at 60° F., less well at 70° (116).

Spirea. Softwood, July, cuttings root readily. There was 80 to 100 percent rooting of untreated cuttings of *S. Bumalda*, *S. salicifolia* (46), *S. Thunbergii*, *S. Billiardii* (66), *S. arguta*, and *S. Vanhouttei* (116), but rooting of some species may be at least hastened by treatment. June cuttings of *S. Bumalda* var. "Anthony Waterer" rooted 100 percent in 4 weeks after treatment with indolebutyric acid (10 mg./l., 24 hr.), 55 percent without it (57). Cuttings of *S. Vanhouttei* rooted 100 percent in 3 weeks after treatment for 8 hours with Hormodin A (40 B T I units), not at all without it (118). Cuttings of *S. arguta* (80), *S. Vanhouttei* (14), and *S. Billiardii* (66) rooted better in sand–peat than in sand.

Stephanandra. Softwood cuttings are easily rooted without treatment. Taken here in July and August, cuttings of *S. Tanakae* rooted 100 percent in sand in 3 to 4 weeks whether or not they were treated. Cuttings of *S. incisa* rooted better in sand than in sand–peat (14).

Stewartia. Cuttings are taken in summer, often in late summer (106). It is English practice to make them with a heel (80, 105). Cuttings of *S. koreana* and *S. ovata* taken here in late July and early August rooted not more than

20 percent without treatment but they rooted 88 to 100 percent in sand–peat in 8 to 10 weeks after treatment with indolebutyric acid (50 mg./l., 20 hr.). Sand (105) and sandy soil (7, 80) have also been used successfully. To induce more of the rooted cuttings to live through the first winter, sometimes difficult, they should be kept in a warm place and, if possible, growing (105).

Styrax. *S. japonica* is not usually propagated by cuttings (104), but untreated softwood cuttings of that species, *S. americana*, and *S. Obassia* rooted well if taken here in mid-July, less well if taken in late August. Taken here in late July, untreated cuttings of *S. japonica* rooted 40 percent in sand, 80 percent in sandy soil; and those which had been treated with indolebutyric acid (12.5 mg./l., 18 hr.) rooted 50 percent in sand, 90 percent in sandy soil. Such treatments sometimes merely hasten rooting. Cuttings of *S. japonica* rooted 100 percent in 8 weeks without treatment and in 3 weeks after treatment (indolebutyric acid 50 mg./l., 4 hr.) (125). December cuttings of *S. americana* responded to treatment with 4 mg./cc. applied by the concentrated solution–dip method (49).

Symphoricarpos can be propagated by cuttings of hard or soft wood (51). Untreated cuttings of snowberry rooted well when taken in June, July, and August (44). Similar cuttings of coralberry, untreated, rooted 100 percent and best with the basal cut a half inch above the base of the current season's growth (46). Late June cuttings of that species rooted, in 3 weeks, 93 percent after treatment with indolebutyric acid (5 mg./l., 24 hr.), 27 percent without it (57). Softwood cuttings of snowberry rooted better in sand than in sand–peat, better at 70° F. than at 60° or 80° (116).

Symplocos paniculata, Asiatic sweetleaf, has been considered difficult to propagate by cuttings (98). Softwood cuttings taken here in early June rooted 58 percent in sand with treatment, 36 percent without it; and similar cuttings in sandy soil rooted 92 percent with treatment (indolebutyric acid 50 mg./l., 24 hr.), 55 percent without it.

Syringa, lilac. Cuttings of *S. vulgaris* root best if taken in spring, May or June here, while new shoots are still growing (49) or very soon after flowering (67, 78, 125). Being very soft, they must be carefully protected against wilting; but taken later, when the wood is harder, they root more slowly and usually in smaller percentages (60). Cuttings taken as late as July are less likely to make good top growth that season (46). Good cuttings are made of shoots, not too vigorous (106), which are not more than six inches long (45). Complete shoots, with the basal cut at the base of the current year's growth (46), root better than parts of shoots (60).

Lilac cuttings root well in sand (78), better than in sand–peat (44, 56, 116). They should be inserted at an angle so that the leaves are almost flat on the sand (45, 60). Shading is more than usually important for such very soft cuttings. Bottom heat has been recommended and cuttings of two species rooted better at 70° F. than at 60° F. (116).

The optimum concentration of indolebutyric acid is not exactly the same throughout the season (cuttings taken early are likely to need a somewhat greater concentration than those taken two weeks later), nor is it exactly the same for all horticultural forms of *S. vulgaris* (60). But their rooting, and the rooting of cuttings of other species (60), is usually improved by treatment with 20 to 60 mg./l., 24 hr., 2 to 12 mg./gm. talc, or, by the concentrated solution–dip method, 4 to 10 mg./cc. (49). Taken here in mid-June, cuttings of Marie Legraye rooted 22 percent without

treatment, 100 percent in 90 days after treatment with 25 mg./l., 24 hr. Similar cuttings of Vestale, more benefited by 50 mg./l., rooted 87 percent with treatment, 36 percent without it. Cuttings of Reine Elizabeth and Siebold, taken in May, rooted 100 percent in about 4 weeks after treatment with indolebutyric acid 12 mg./gm. talc (49). Similar cuttings of *S. villosa*, *S. Henryi*, *S. tomentella*, and Persian, Hungarian, and Himalayan lilacs rooted not more than 25 percent without treatment, but 75 to 100 percent after treatment with indolebutyric acid (40 mg./l., 24 hr.) (60). Indoleacetic acid is also effective (87), and a treatment of lilac cuttings with naphthaleneacetic acid (20 mg./l., 24 hr.) was highly beneficial (47). Cuttings of the variety Mme. Lemoine taken here in early July, too late for best results, rooted 17 percent without treatment, 34 percent with indolebutyric acid (25 mg./l., 22 hr.), 48 percent with naphthaleneacetic acid similarly used, and 63 percent with naphthaleneacetic acid (100 mg./l., 5 hr.).

Tamarix, *tamarisk*. Softwood, summer, cuttings root readily in sand (106). Untreated late June cuttings of *T. odessana* rooted 90 percent in 3 weeks (57) and similar cuttings of *T. pentandra* rooted about equally well (66).

Taxus, yew. Cuttings of Japanese yew rooted best when taken in December (13), December and January (31), or January (103), but cuttings of this and other yews also root well when taken in October and November. August cuttings will root in a cold frame but more slowly than do fall cuttings in a greenhouse (123, 125). The basal cut is made at the base of a year's growth, usually that of the current year, but it can be lower. Cuttings of Canada yew rooted practically equally well when they had wood one, two, or three years old at the base, but the latter types result more quickly in larger plants (69). Cuttings have rooted well in sand–peat (29, 57); better, in the case of *T. media* and Japanese yew, in sand (14, 21, 57). Cuttings of *T. media* taken here in November and December rooted better in sand–peat than in sandy soil whether or not they were treated. Bottom heat, 68° to 70° F., improved the rooting of cuttings of that species (31).

Rooting of untreated cuttings of yews is generally slow but sure and the commonest effect of treatments is to hasten rooting. Cuttings in the first stages of dormancy are benefited by higher concentrations than are those taken later (57). Cuttings of three species responded to treatment with indolebutyric acid (40 or 80 mg./l., 24 hr., or 12 mg./gm. talc) (61). Cuttings of a variety of English yew which were taken here in early December rooted 100 percent in 5 months without treatment, in 3 months after treatment with indolebutyric acid (75 mg./l., 24 hr.). Cuttings of *T. media* taken here in late January responded in the same way to treatment with 50 mg./l., 24 hr. Indoleacetic acid (50 mg./l., 12 hr., or 100 mg./l., 16 hr.) also improved or hastened rooting of cuttings of yews (21, 83), and naphthaleneacetic acid (40 mg./l., 24 hr.) was very effective with fall and winter cuttings (47)—rather more effective in fact, than indolebutyric acid (58). Naphthaleneacetic acid (33 mg./l., 24 hr.) also hastened rooting of summer cuttings (113).

Thuja, arbor-vitae. Cuttings are usually taken in fall and winter. There was good rooting of cuttings of American arbor-vitae, made of the current year's wood with a heel, which were taken here in every month from November to March, but those taken in and after January rooted a little more quickly. January cuttings of giant arbor-vitae also rooted well (123, 125). August cuttings of American arbor-vitae (var. *robusta*), in a cold

frame, rooted more slowly but as well finally as did fall and winter cuttings in a greenhouse (123). Sand–peat (14) or sandy soil (27) gave better results than sand as a rooting medium. Cuttings of nine varieties of American arbor-vitae responded to treatment with indolebutyric acid (40 to 80 mg./l., 24 hr., or 12 mg./gm talc) (61). Cuttings taken here in January rooted 100 percent whether or not they were treated (100 mg./l., 16 hr.), but treated cuttings rooted in less time by about four weeks. The only effect of treatment (80 mg./l., 20 hr.) of October cuttings of the variety *globosa* and January cuttings of giant arbor-vitae was, similarly, to hasten good rooting (125). November cuttings of the latter (var. *atrovirens*) rooted 75 percent in about two months after treatment (50 mg./l., 24 hr.), 15 percent without it (57). Such treatments not only hasten rooting but may also increase percentages which root finally. With sandy soil as the rooting medium, cuttings of oriental arbor-vitae which were taken here in December rooted 78 percent with treatment (50 mg./l., 24 hr.), 37 percent without it; and December cuttings of *T. occidentalis* var. "*Douglasii pyramidalis*" rooted 100 percent with treatment, 62 percent without it.

Thujopsis dolabrata, Hiba arbor-vitae. Cuttings do not root readily, but those taken in summer and treated with indoleacetic acid (50 mg./l., 24 hr.) rooted 45 percent more in 3 months than did untreated cuttings (113).

Tripterygium Regelii. Hardwood cuttings taken here in late March, buried in sand in a cold cellar for a month, and then lined out in the field, rooted 100 percent in 9 weeks whether or not they were treated.

Tsuga canadensis, common hemlock. Cuttings, if treated, have rooted well when taken in September or October (109), November (24), January (125), March or April (61), and early summer, although early summer cuttings, being soft, are difficult to keep in good condition (49, 126). Summer (49), fall, and winter cuttings of this species (and *T. Sieboldii*) responded to treatment with indolebutyric acid (40 to 80 mg./l., 24 hr., or 12 mg./gm. talc) (61). January cuttings rooted 79 percent in 62 days after treatment (50 mg./l., 22 hr.), not at all without it (125). Cuttings of the variety *pendula* which were taken here in early September rooted 83 percent in sand–peat with treatment (50 mg./l., 24 hr.), 34 percent without it. November cuttings rooted 5 percent without treatment, 65 percent after treatment with indolebutyric acid (4 mg./gm. talc) (24). November cuttings of a dwarf hemlock growing in southern Vermont and making not more than one inch of new growth a year were here made with the basal cut at the base of the two-year-old wood. Best results and most rapid rooting, 80 to 96 percent in sand–peat in 11 weeks, followed treatment with indolebutyric acid, 100 mg./l., 16 or 24 hr., or 200 mg./l., 8 or 12 hr., rather than lesser concentrations. There was at that time no rooting of untreated cuttings although all were still living. Summer (44) and winter (125) cuttings have also rooted well in sand.

Ulmus, elm. Oriental elms (124) and white elm can be propagated by softwood, spring, cuttings. New shoots of Siberian elm, taken when they were four to six inches long, rooted in 4 weeks (127). June cuttings of that species and of Chinese elm rooted well in sand (44). Cuttings of Siberian elm rooted best, more than 80 percent, with the basal cut a half inch above the base of the current season's growth (46). Cuttings of white or American elm taken here in early June rooted 94 percent in 5 weeks after treatment with indolebutyric acid (50 mg./l., 24 hr.), 23 percent in 12 weeks without treatment. Cuttings of Siberian elm rooted 60

percent in 25 days after treatment with Hormodin A (80 B T I units), not at all without treatment (118).

Vaccinium corymbosum, highbush blueberry. Propagation by hardwood cuttings is well described by Bailey and co-workers (4) and their paper should be read for details beyond those given here. Cuttings 3 or 4 inches long are made in late March, before buds begin to break, or they may be taken earlier in the winter and stored cool in moist sphagnum until spring. They are made of such of the previous year's growth as bears no fruit buds and is not too weak, with the basal cut just below a bud, the top cut just above a bud. They should be set so deeply in the rooting medium, sand–peat, that only the top bud is out of it. Untreated hardwood cuttings which were taken here in mid-March rooted 100 percent in sand–peat in the case of the varieties Rubel and Harding, 50 to 88 percent in the case of Adams, Jersey, and Pioneer. Their rooting here, as elsewhere (54), was not improved by treatment with root-inducing substances.

Softwood cuttings taken in or about July (44, 53), are made with the basal cut at or near the base of the current season's growth, with few or no leaves removed (46). They should be set deeply in the rooting medium, sand–peat. Rooting of June and July cuttings of Rubel was improved by treatment with indolebutyric acid (20 to 40 mg./l., 24 hr., or 2 to 5 mg./gm. talc) (49). Softwood cuttings taken here in July and treated with indolebutyric acid (50 mg./l., 20 hr.) rooted in sand–peat as follows: Jersey, 100 percent in 40 days; Cabot, 80 percent in 35 days; Wareham, 77 percent in 27 days. Untreated cuttings rooted 50, 33, and 42 percent.

Vaccinium Vitis-idaea, cowberry. Untreated cuttings which were taken here in early August rooted more than 90 percent in sand–peat in 8 weeks. Results were less good in sand or if cuttings were taken in late September.

Viburnum. Spring and early summer is a good time to take softwood cuttings. Taken here in late June or early July, untreated cuttings of *V. tomentosum, V. rhytidophyllum, V. fragrans, V. Sieboldii,* and European cranberry-bush rooted 80 to 100 percent. Hardwood cuttings of some species also root well (67). Treatments with indolebutyric acid improve or at least hasten rooting. Cuttings of *V. Carlesii* taken here in early June rooted 100 percent in 7 weeks after treatment (20 mg./l., 18 hr.), 59 percent without it. Rooting of late June cuttings of that species was hastened by 30 mg./l., 6 hr. (16). Concentrations may need to be increased if cuttings are taken later in the summer (83), but rooting of July cuttings of the following was improved by these treatments: *V. tomentosum,* 5 to 20 mg./l., 24 hr.; arrow-wood, 5 mg./l., 24 hr. (57); *V. Sieboldii,* 10 mg./l., 24 hr.; European cranberry-bush, 10 mg./l., 6 hr. (83). Also effective are 2 mg./gm. talc, or, by the concentrated solution–dip method, 4 mg./cc. (49). Cuttings of six species rooted better in sand–peat than in sand (14). Sandy soil is also good. Cuttings of *V. Carlesii,* untreated, rooted better in sandy soil than in sand (27). Cuttings of hobble-bush taken here in mid-July and treated with indolebutyric acid (50 mg./l., 20 hr.) rooted 67 percent in sandy soil, 25 percent in sand.

Vitex. Hardwood cuttings of chaste-tree taken here in late March, buried in moist sand at about 50° F. for four weeks, and then planted outdoors, rooted 79 percent without treatment, no better with it. Softwood, July, cuttings of *V. Negundo* (var. *incisa*) rooted 64 percent in 22 days after treat-

ment with indolebutyric acid, only 4 percent without it (83). Similar cuttings of chaste-tree rooted 100 percent in sand–peat in 32 days after treatment with indoleacetic acid (100 mg./l., 24 hr.) (87). Sandy soil is successfully used as rooting medium for both species (80, 106).

Vitis, grape. Hardwood cuttings respond to treatments (130), although less, at least in the case of Concord, than do greenwood, summer and fall, cuttings. Hardwood, April, cuttings of Concord which had been treated with indolebutyric acid (80 mg./l., 24 hr.) produced many more roots per cutting than did the untreated, and a concentration of 10 mg./l., 24 hr., had a similar effect on softwood cuttings (48). November cuttings of that variety responded to 40 mg./l., 24 hr.; 2 to 10 mg./gm. talc; or, by the concentrated solution–dip method, 10 to 25 mg./cc. (49). August cuttings of muscadine rooted 44 percent in 3 weeks after treatment with indolebutyric acid (20 mg./l., 20 hr.), not at all without it (125).

Weigela. Hardwood cuttings of a hybrid which were taken here in late March and immediately set in sand–peat in the greenhouse rooted 90 percent in about 9 weeks, with no benefit from indolebutyric acid. Softwood, summer cuttings, usually root well in sand (14, 44, 105, 106). There was good rooting of untreated cuttings of *W. floribunda* taken from June through September (44). Probably the best place for the basal cut is above a node (106). Indolebutyric acid at least hastens rooting of such cuttings. Late June cuttings of *W. florida* rooted 72 percent in 20 days after treatment (50 mg./l., 12 hr.), not at all meanwhile without it; and August cuttings of a hybrid rooted 95 percent in one month after that treatment, 30 percent without it (83). July cuttings of another hybrid rooted 90 percent in 14 days after treatment with 20 mg./l., 24 hr. (57). Equivalent concentrations of indolebutyric acid for October cuttings of the hybrid Mme. Ballard are 10 mg./l., 24 hr., or 2 mg./gm. talc, or by the concentrated solution–dip method 4 mg./cc. (49).

Wisteria, wistaria. Softwood cuttings of Japanese wistaria which were taken here in mid-July rooted 100 percent in sand–peat in 2 months after treatment with indolebutyric acid (25 mg./l., 24 hr.), 80 percent without it. July cuttings of Chinese wistaria, treated, rooted well in sand–peat (68, 87). Fall cuttings of wistarias will also root, although slowly (124).

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 383 March, 1941

The Sanitary Evaluation of Private Water Supplies

By Ralph L. France

A safe water supply for rural homes is of prime importance. This is an explanation of some of the problems involved, with special attention to contamination and its detection.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS

THE SANITARY EVALUATION OF PRIVATE WATER SUPPLIES

By Ralph L. France, Assistant Research Professor of Bacteriology.

Introduction

Water is a prime factor in the support of all forms of life. While not classified as a food, yet it is a necessary item in the diet. The value of an abundant and pure water supply has been known from remote times. Hippocrates, some four hundred years before the beginning of the Christian era, wrote that a polluted water should be boiled and filtered before it was used for drinking—certainly a most up-to-date piece of advice.

Centers of population sprang up around places where water was available. Where it was not available, extraordinary means were taken to transport it. In Egypt and India today are to be found ruins of what must have been great hydraulic works. Some were constructed at least two thousand years before Christ. The great aqueducts of Rome were built some few years before the Christian era. When one reflects that these works of antiquity were constructed before the advent of steam, electricity, and explosives, one is impressed with the great intelligence and perseverance exhibited by these early engineers.

The fact that water can intensify and spread certain diseases was suspected long before the discoveries of Pasteur and the germ theory of disease. As the knowledge of bacteriology and sanitation has been advanced by new discoveries, the number of epidemics caused by contaminated water has been gradually reduced. In spite of the present advanced knowledge in sanitation and water works practice, some epidemics of typhoid and dysentery still do occur. In most cases they can be traced to a lack of alertness, or a lack of proper application of modern knowledge, on the part of those responsible for the purity of the supply.

It is the object of this bulletin to discuss rural private water supplies, laying particular stress on the possibilities of their becoming contaminated with disease producing bacteria; to explain the type of test used in the laboratory to detect contamination; and to analyze the results of more than 1,000 tests made during the past ten years on rural private water supplies located in this State.

Classification of Water

"For practical purposes water may be classified as *clean, polluted,* or *contaminated.* (1) A *clean* water is one which at all times is free from contamination or pollution, and safe for human consumption, as determined by laboratory analysis, sanitary survey, and continued use. (2) A *polluted* water is one which has suffered impairment of physical properties through the addition of substances causing turbidity, color, odor, or taste. (3) A *contaminated* water is one which carries potential infection by reason of the addition of human or animal wastes, or has been rendered unwholesome by poisonous chemical compounds." (Rosenau—Preventive Medicine and Hygiene, 6th ed., 1935).

According to their sources, waters are classified as rain water, surface water, or ground water. (1) Rain water is really a "distilled water"; that is, a water that has been vaporized and condensed. Distillation is one of the best-known methods for purifying liquids. Thus, if properly collected, rain water should be the purest type of water.

(2) Surface waters, i. e., ponds, creeks, rivers, lakes, etc., vary greatly in composition and are subject to impurities. From a sanitary standpoint they are the most dangerous type of water to be used for drinking. Most cities in America depend upon surface water for their supply. It is hardly possible in a populous country to obtain any great amount of surface water free from contamination with human wastes. It is for this reason that the modern water-treatment plant has been constructed. By the use of filtration and chlorination these plants render the water safe for human consumption.

In reality, streams are the natural sewers for the regions they drain. It is inadvisable to use surface water as a source of supply without first treating it to remove impurities.

(3) Ground water is the type almost universally used as a source of supply for rural homes. It is usually satisfactory as far as impurities go. As water percolates through the soil certain impurities are removed by the natural filtering properties of the soil. The soil can take care of a large amount of impurities if not over-burdened, or if there are no cracks or crevices.

When water soaks into the soil it will finally come to rest upon an impervious stratum. With its downward motion finally stopped, it then spreads out in a horizontal plane, forming what is known as the *ground water table.* This ground water table underlies practically all the earth's surface.

Ground water may be divided into three types depending upon the depth at which it is tapped. (a) Spring water is ground water that comes out on the surface because of the topography of the land. Spring water does not necessarily differ in composition from other types of ground water. It is of a high degree of purity and can be easily utilized if it has a good flow. Spring water, however, can easily become contaminated unless proper precautons are taken to protect it. The protection of springs against contamination requires a careful study of each location.

(b) Shallow well water is obtained from a source in which the ground water table is very near the surface. It is perhaps the hardest type of well water to protect from contamination, particularly in a dug well.

(c) Deep well water is that usually obtained at a depth of 50 or more feet. It is generally the purest of ground waters, and the easiest to protect against contamination. Artesian wells are of this type. The water is mostly obtained by suction pumping or by means of compressed air.

Contamination of Water Supplies

The greatest hazard to man in drinking water is found in a water contaminated with the discharges from the human body, i.e., *feces, urine,* and *sputum.* There is really little danger from water containing the waste materials from other animal life, for the reason that few of the diseases contracted by the lower animals are transmissible to man. There is still less danger from organic matter of plant origin.

The only diseases which in this State may be contracted by drinking contaminated water are typhoid fever and dysentery. There has been some suggestion that jaundice might be transmitted in this manner but proof of this is lacking.

Now the chance in this State of contracting typhoid or dysentery *from any source whatsoever* is about 1 in 500,000. The Massachusetts State Board of Health, in their Annual Report for 1939, list only 78 cases of typhoid fever as occurring in the entire State for that year. The total number of dysentery cases for the same period was 491. This latter figure may seem rather high but further study of the Report shows that most were of epidemic form and located in institutions.

In a personal communication from Dr. Roy F. Feemster, Director of the Division of Communicable Diseases, the following comment is made:

> We make a careful investigation of each case of typhoid fever and bacillary dysentery and there is little in our records to indicate that any of the cases in 1939 or in the years immediately preceding were contracted because of contaminated private water supplies. Bacillary dysentery may occasionally be transferred in this way but I have considerable doubt as to whether any of our typhoid cases result from the drinking of contaminated water. You will be interested to know that practically all of our typhoid cases occur singly and it is hard to believe that a water supply could cause one case in a family and not affect other individuals using water from the same source. The reason for this condition can be attributed to a number of factors, among them the alertness of people of this area to make sure that water supplies are satisfactory and the fact that we are in a glacial region containing sand which acts as a natural sand filter.

To these reasons we would add another rather obvious one. In the case of any water supply the only persons capable of contaminating that supply are those living in its immediate vicinity. If none of these persons contracts typhoid or dysentery from an outside source, or if none of these persons is a carrier of the disease organisms, then it is practically impossible for such bacteria to gain access to the supply. Even if the drainage from a cesspool, backhouse, or any other sewage disposal system were to run directly into the well, it would still be practically impossible for persons drinking the water to contract typhoid or dysentery from that water.

The floods of 1936 present a fine illustration of the fact that the chances of contracting disease from drinking contaminated water are, in this State, practically nil. In our knowledge hundreds of wells were inundated with polluted flood water. In many cases the water was used for drinking before health authorities had the chance to purify the water. Yet no case of typhoid fever resulted from these conditions.

However, even if a contaminated water may not cause a specific disease, no one cares to drink it. Whether the contamination is of human or animal source makes little difference; it is not a desirable water for human consumption. There is some evidence to indicate that while water containing sewage material may not cause a specific disease, it may cause intestinal upsets of varying intensity. It is here that the laboratory test renders its greatest service, for this test is designed to detect minute amounts of sewage material rather than actual disease-producing bacteria.

The Laboratory Test

Most uninformed persons seem to think that all the bacteriologist has to do to determine the purity of a water is to put a drop of it on a glass slide and look at it through a microscope, and that if any typhoid or dysentery bacteria are present they would be seen and recognized. Bacteriologists wish it were as simple as that. But it is not, and for the following reasons:

In the first place, it would be impossible to concentrate water to the point where a single drop would contain sufficient bacteria to be seen.

In the second place, under the microscope bacteria can be identified only by the following general shapes and formations:

1. Spirilla. Here the cells are spiral, or corkscrew-like, in appearance.
2. Cocci. These cells are spherical in shape and appear in the following formations:
   a. Staphylococci, bunched like grapes.
   b. Streptococci, in chains of varying length.
   c. Diplococci, in pairs.
   d. Some other formations which need not be mentioned here.
3. Rods. Here the cells are somewhat rectangular in shape.

It is true that by certain staining methods further identification within these groups can be made. However, identification by microscopic methods would still be very general, so that within each of these groups would be hundreds of species which must be identified by other than microscopic methods.

Both the typhoid and dysentery organisms belong to the third group; that is, they are rod shaped. To the bacteriologist these forms are known as "bacilli." Under the microscope, even with the use of stains, it is impossible to distinguish between them. Further, there are normally present in water many other rod-shaped bacteria which are similar in appearance to the typhoid and dysentery bacilli, but which are harmless. Therefore, a direct microscopic examination of a water would supply little if any information regarding its purity.

The major methods used in identifying and classifying all bacteria are of a chemical and physical nature. They can be very simply explained as follows. Bacteria, like plants and animals, are living organisms. The main difference between the bacteria and higher forms of life is that the former are single-celled while the latter are multicelled. Being alive, bacteria must "breathe," they must "eat," and they must discharge the by-products of that "breathing" and "eating"; even as all animals do. By cultivating the organisms in known kinds of atmospheres, and by "feeding" them known kinds and amounts of food, then analyzing the by-products both chemically and physically, it is possible to identify and classify them. Another factor that assists is the source of the organism. Many species of bacteria, like many plants and animals, live and multiply best in certain localities. With bacteria it may be the oral cavity, the intestines, or the skin of man or animal; with plants and animals it may be geographic locations.

It is by these methods then, rather than by the microscope, that the bacteriologist determines the purity of a water supply. It will be noted that the term used was "determines the *purity* of a water supply," not

"determines whether or not the water contains typhoid or dysentery bacteria." For, and again some readers will be disappointed, even with these chemical methods, no attempt is made to isolate disease-producing bacteria from the water. In other words, in the bacteriological test of water no attempt is made by any method to determine whether or not the water under test contains typhoid or dysentery bacilli. The reasons for this are easily understood.

As explained above, the microscope is of little practical value in determining the purity of water. To date bacteriologists have been unable to devise a direct method that is both economically and technically satisfactory for the isolation of disease-producing bacteria from water. As stated above, there are normally present in water many other rod-shaped bacteria which are harmless in so far as disease-producing capacities are concerned, but which so closely resemble the typhoid bacilli in microscopic appearance and in their "breathing" and "eating" habits that it is possible to distinguish among them only by highly specialized methods. In a routine water analysis such highly specialized methods are not desirable from an economic standpoint, if for no other reason. The disease-producing bacteria are for the most part rather "fussy" in their habits. The harmless bacteria on the other hand are more rugged, more vigorous, than the disease-producers. One might say that these latter organisms are the "aristocrats" of the bacterial world while the harmless ones are the "peasants" or "workers." When mixed together the harmless bacteria will outgrow and outlive the disease-producers. This is particularly true in a medium such as water, where the food supply is generally very limited. This is another reason why it is so difficult to isolate typhoid and dysentery bacilli from a contaminated water. So, instead of using a direct method for the isolation of disease-producing bacteria from water, the bacteriologist makes use of an indirect method.

There normally is present in the intestines of man and animals an organism known as *"B. coli."* This strain of bacteria is given off in the waste materials in large numbers. The organism is harmless, and resembles the typhoid and dysentery bacteria in that it is rod-shaped. It can be rather easily identified by somewhat simple cultivation methods. The presence of this organism in a water supply indicates that the supply either is or has been receiving waste material of animal or human origin. The numbers present will indicate to some degree the extent of contamination. The argument presented when this test was devised was, of course, that if *"B. coli"* could gain access to a water supply then typhoid or dysentery bacteria might also gain access to the supply. Thus in the laboratory test this *"B. coli"* organism is used as an "indicator" of contamination in water. This is what was meant when it was said that the laboratory test was an indirect test rather than a direct test.

So far it has been impossible to distinguish in the laboratory between the *"B. coli"* of human origin and that of animal origin, and there is little reason to believe that such a distinction would have any practical value in routine water testing. If either type is present in a water it means that faulty construction or poor location is responsible. The mere presence of *"B. coli"* in a water supply, be it of human or animal origin, indicates that the water is unsatisfactory for drinking purposes. And, further, drinking water containing waste material from any source is potentially dangerous.

It is only fair to call the reader's attention to the fact that this bacteriological test is not infallible. Water should not be judged wholly on such a test. A common-sense sanitary survey of the supply and its immediate surroundings should supplement the laboratory analysis. In most cases this survey will indicate the source of contamination and the kind—whether it is of human or animal origin. Further, there may be occasions when the laboratory test fails to reveal any contamination, but the sanitary survey may show certain potential sources of contamination. Such a condition should arouse questions about the future purity of the supply even though the present laboratory tests failed to reveal any impurities. This survey will reveal also faulty construction in the supply, which is an important item particularly in shallow dug wells. If persons building new homes in rural areas would only remember to locate their water supply first, and then so construct their homes that the disposal of waste materials can not contaminate the supply, little trouble would ever be experienced with impure drinking water.

The results of a single analysis are not always too dependable. A drought or a rain storm just previous to sampling can influence the results considerably. As Dr. Feemster points out in his letter to the writer:

> No doubt in your bulletin you will emphasize the fact that bacterial examination of water should not be depended upon solely to give an idea of the safety of a particular supply since a sample taken during a wet period or after a heavy rainfall might show evidences of pollution of a well which under more favorable circumstances might appear by bacteriological examination to be perfectly safe.

Careless sampling methods, and careless handling of the sample between sampling and testing, can also influence the results considerably.

Before concluding this section some mention should be made of chemical tests of drinking water. In the laboratory at the Massachusetts State College chemical analyses of drinking water are not made. One reason is the belief that the bacteriological test is a much more dependable and sensitive test than the sanitary chemical test. The bacteriological test can detect minute amounts of contamination which might be missed in the chemical tests. Further, the chemical analysis is of little value when applied to rural private water supplies unless several such tests can be made over a considerable period of time. Individual waters vary considerably in their chemical composition, and unless normals have been established by means of frequent tests it is difficult to justify an opinion of the quality of the water upon one test. In the case of town and city water supplies the State Board of Health makes frequent routine chemical analyses of the supplies. This has been done for many years, and in this way it has been possible for them to establish normals for the several chemical components of the water. If at any testing period results show that any one or several of these chemical components varies from the normal, check tests, as well as an immediate sanitary survey, are made to locate the source of the change. Incidentally, the bacteriological analysis is one of the most important check tests.

In conclusion there is another type of chemical analysis for which frequent requests are made. So far as we know there is no water in the State of Massachusetts that might contain any one, or several, chemical

compounds which might have a medicinal "cure-all" value. Frequently persons send us samples of water which they believe to contain some unusual chemical constituent with remarkable curative properties for practically all known human ailments. Our answer is that there is no such water and such analyses can not be made.

All analyses of this type, as well as analyses to determine what type of piping or hot water tank to install, should be referred to a commercial laboratory. The laboratory at the Massachusetts State College deals only in health applications of any tests made.

Results of 1,016 Analyses

A very brief survey of 1,016 analyses made in the Service Laboratory during the past ten years is presented in the final section. The very fact that these samples were sent in to us for analysis suggests that in the majority of cases some doubt existed in the minds of the owners as to the purity of their supplies. Therefore a rather high percentage of contaminated supplies is to be expected. The reader must not interpret the final figures given in tables 1 and 2 to imply that this is a general picture of the condition of the rural private water supplies in the State of Massachusetts. These figures mean just what they represent: that 44 percent of all the supplies suspected of being contaminated, and *sent to the laboratory to be tested*, were contaminated.

TABLE 1.—TOTAL NUMBER AND TYPE OF EACH SUPPLY TESTED, AND THE NUMBER AND PERCENTAGE OF EACH SHOWING CONTAMINATION.

Type of Supply	Total Number Tested	Number Contaminated	Number not Contaminated	Percent Contaminated
Spring	193	77	116	39
Dug Well	452	250	202	54
Driven Well	332	119	213	35
Totals	977	446	531	45

Table 1 presents the total number of samples tested from each type of supply together with the number and percentage of each that showed contamination. These results show, as might be expected, that the highest percentage of contaminated supplies occurred in the group classified as dug wells. Being for the most part rather shallow (the average depth of those tested was only 15 feet), dug wells are the most difficult type of supply to protect from contamination. The majority of those tested were of rather ancient vintage; that is, from 30 to 150 years old. At the time of their construction a general knowledge of water sanitation was lacking. Field stone was used as a curbing, and the cover, if any, was of loosely laid planks. Further, for convenience the well was located in or near the house. So also were the toilet facilities. The result is obvious. The loosely laid field stone curbing and plank cover allowed surface-water contamination, while the nearness to the sewage disposal system resulted

in sewage contamination. Modern knowledge of water sanitation, requiring a tight tile curbing and a tight metal or stone cover, in addition to proper location of the supply, results in a fully protected drinking water supply.

As stated previously, spring water as it emerges from the ground is generally of high quality. Contamination of the supply occurs only after the water has emerged from the ground, and it is for the most part of the surface-drainage type rather than the sewage type. Proper excavation back to the actual point where the water emerges and a well-constructed spring house will prevent this subsequent contamination.

The records show that in practically every case where contamination occurred in a driven well it could be traced to a poor location. It is true that soil will act as a natural filter for the water percolating through it. However, when it becomes saturated with impurities, it then ceases to act as a filter. Further, even though the source of the impurities was removed, it still would take the soil a considerable length of time to purify itself. The answer to this problem is to so locate the well in respect to the waste disposal systems from the house that no contamination from these sources can gain access to the well, or to the soil immediately surrounding the well.

TABLE 2.—LOCATION OF SUPPLIES TESTED, BY COUNTIES, AND THE NUMBER AND PERCENTAGE SHOWING CONTAMINATION.

County	Total Number Tested	Number Contaminated	Number not Contaminated	Percent Contaminated
Nantucket	0	0	0	0
Dukes	0	0	0	0
Plymouth	9	0	9	0
Bristol	17	7	10	41
Barnstable	118	29	89	24
Norfolk	3	1	2	33
Suffolk	8	7	1	87
Middlesex	21	6	15	28
Essex	17	11	6	64
Worcester	223	121	102	54
Hampden	104	41	63	40
Hampshire	235	118	117	50
Franklin	184	84	100	45
Berkshire	77	29	48	37
Totals	1,016*	454*	562*	44*

* Includes drilled wells.

In table 2 the supplies tested are classified by counties. Here again the results given are in no way a reflection on the general condition of the private supplies located in the respective counties.

As might be expected, the majority of the supplies tested were located in counties near to the laboratory. The 118 samples received from Barnstable County were an exception to this. It is interesting that the lowest percentage of contaminated supplies also occurred in the case of the supplies tested from this County. This directly reflects the fact that people are becoming more alert to make sure their water supplies are satisfactory, for most of these supplies were of new construction. This is brought out more clearly when the results of Barnstable County are compared with those of Worcester, Hampden, or Hampshire Counties. In the case of these three latter counties the majority of supplies tested were not newly constructed.

It has been the intention in preparing this bulletin to present certain information, little known or little understood by the public, regarding the contamination in, and the bacteriological testing of, rural private water supplies. The contamination of such supplies with typhoid and dysentery bacteria has ceased to be a public health problem in Massachusetts. The State Board of Health Reports for the past few years fail to reveal any case of typhoid fever directly traceable to the drinking of contaminated water from a rural private supply.

Water can and does, however, become contaminated with the waste materials from man and animals. The routine bacteriological test is designed to isolate and identify an organism known as "*B. coli,*" which is present in large numbers in the feces of man and warm-blooded animals. This organism is used as an indicator of the presence of fecal material in water. The test is both sensitive and dependable, for the presence of such material in a drinking water supply is at least objectionable, and should always be considered as potentially dangerous. No attempt is made in this test to directly isolate disease-producing bacteria from the water.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

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The Importance of Length of Incubation Period in Rhode Island Reds

By F. A. Hays

This represents an attempt to determine whether length of incubation period may serve as a criterion of the future performance of chicks.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE IMPORTANCE OF LENGTH OF INCUBATION PERIOD IN RHODE ISLAND REDS*

By F. A. Hays, Research Professor of Poultry Husbandry

INTRODUCTION

A limited amount of preliminary unpublished data on Barred Plymouth Rocks, collected by Dove (1935) at the Maine Station, suggested that chicks emerging early from the shell were more likely to be females than males and that such chicks were probably more viable than chicks emerging later. It is also commonly observed, in chicks from the same setting of eggs, that those emerging late are less likely to survive and often grow more slowly than those emerging early. Such observations suggested the possibility that the length of the incubation period might be a useful criterion of the future outcome of chicks. A study of the length of incubation period for Rhode Island Reds in its possible relation to sex, viability, and characters affecting fecundity was therefore undertaken in the spring of 1937 and continued through three hatching seasons.

Data Available

All chicks were pedigreed Rhode Island Reds hatched in the same forced-draft electric incubator in 1937, 1938, and 1939. Observations covered six hatches obtained at weekly intervals between March 7 and April 23. Seven emergent periods, each covering eight hours, were included in the study. The first chicks appeared during the last third of the 20th day and the last chicks appeared during the last third of the 22d day under the methods of incubation used. Data were secured on 4730 chicks in the three-year period. Records were taken on sex, mortality at different ages, body weight at about six months of age for both males and females and at sexual maturity and at the end of the first laying year for females, age at sexual maturity in females, winter and annual egg production, and the emergent period of chicks from sires and dams classified according to their individual emergent periods.

In order to reduce to a minimum the temperature shock to the newly hatched chicks, it was necessary to keep the chicks out of the incubator for the shortest possible time during each eight-hour observation. For purposes of identification a series of water colors was used for marking. It was found that the color mark was most satisfactory when placed beneath the wing with a small brush. The pedigree baskets were opened at each eight-hour observation. All chicks that were out of the shell at the first observation were marked; and at the second and later observations, all unmarked chicks were given the respective color mark for the period. When the hatch was taken out of the incubator at the end of the 22nd day, the emergent period of each chick was recorded. It was found that the chicks could be gone over and marked in a short time by this method.

*Special credit is due J. W. Locke, Plant Foreman, for assisting in the observations on time of emergence.

EXPERIMENTAL RESULTS

Relation of Length of Incubation Period to Weight of Eggs

Huggins and Huggins (1941) have recently reviewed the literature on variation in the length of the incubation period in wild birds. These workers are of the opinion that fresh egg weight is an important factor in observed variability.

Byerly (1934) and McNally and Byerly (1936) found egg weight to be an important factor in variation in length of the incubation period. Heavier eggs generally required a longer incubation period than lighter eggs.

In the studies here reported, the mean weight of the first ten eggs laid during the hatching season was used as a measure of egg weight. By setting this mean against the emergent period of each chick from the respective dams, the correlation between egg weight and length of incubation period was approximated.

There were 430 dams that laid at least ten eggs and the mean egg weight of these dams was tabulated against the emergent period of their 4730 chicks in a correlation table. The constants arrived at were as follows:

Number of dams	430
Number of chicks	4730
Mean egg weight of dams, grams	62.1
Mean emergent period of chicks	4.2 (last third of 21st day)
Coefficient of correlation	$-.0981 \pm .0097$

Regression was found to be strictly linear, so that the coefficient of correlation may be used to measure association. Using either 400 or 500 degrees of freedom, the magnitude of the coefficient of correlation is insufficient to be definitely significant. It seems apparent, therefore, that this small negative value of the coefficient of correlation indicates no relation between weight of eggs and length of the incubation period in Rhode Island Reds.

Relation of Hatching Date to Length of Incubation Period

The range in hatching dates was limited, extending from March 7 to April 23. All the data are thrown together in table 1 to indicate the percentage of chicks emerging in the different periods as the hatching season advanced.

The data indicate that the majority of chicks hatched in periods 3, 4, and 5 which represent the second third of the 21st day, the last third of the 21st day, and the first third of the 22d day. The number hatched on the last third of the 20th day was extremely small, and the number hatching at the end of the 22d day was also small.

In the hatches produced at the end of March and during the first half of April, there were fewer early emerging chicks and a significant increase in the number of chicks emerging on the 22d day of incubation. The first two hatches, produced before March 15, agreed closely in the percentage of chicks emerging during the different periods. A slight tendency was observed in the third hatch, produced after the middle of March, for the chicks to emerge somewhat earlier than was noted in the first two hatches. Since there was a tendency for the chicks in the earlier hatches to emerge somewhat earlier than in the later hatches, this may in part account for a more rapid growth in chicks from the earlier hatches during incubation, to two weeks, and to four weeks, as reported by Hays and Sanborn (1929).

TABLE 1. — PERCENTAGE OF CHICKS EMERGING IN DIFFERENT PERIODS, BY HATCHES, WITH SUMMARY OF TIME OF EMERGENCE OF ALL CHICKS

Emergent Period	Percentages of Chicks Emerging						Summary of Chicks Emerging	
	Hatch 1	Hatch 2	Hatch 3	Hatch 4	Hatch 5	Hatch 6	Total Number	Percent
1.......	—	.38	1.07	—	—	.24	15	.34
2.......	3.13	4.02	7.20	—	—	3.39	161	3.63
3.......	22.86	20.86	28.46	8.62	6.01	23.00	916	20.64
4.......	40.95	44.98	43.72	38.90	37.19	38.01	1,848	41.65
5.......	24.18	22.20	14.93	37.60	36.75	25.67	1,080	24.34
6.......	5.59	3.83	4.19	13.58	17.15	8.23	310	6.99
7.......	3.29	3.73	.43	1.31	2.90	1.45	107	2.41

Mean Length of the Incubation Period in the Normal Hatching Season

As previously indicated, the chicks were hatched in March and April, and this may be considered the normal hatching season for this locality. All of the hatches during the three-year period have been thrown together in the "Summary" in table 1 to get a general picture of the proportions of chicks emerging during each of the seven 8-hour periods under the uniform conditions of incubation used.

About 42 percent of the chicks emerged during the last third of the 21st day of incubation. At the end of the 21st day only 66.26 percent of the chicks had emerged. The remaining one-third hatched during the 22d day of incubation. Precautions were taken to have the incubator heated to about 100° F. for several hours before receiving the eggs, and the temperature was maintained within a half degree of the manufacturer's recommendations. The data in general indicate that there was a wide fluctuation in the length of the incubation period, which may or may not be a normal condition.

TABLE 2. — PERCENTAGE OF MALES FROM DIFFERENT EMERGENT PERIODS

Emergent Period	Percentage of Males
1	20.00
2	40.99
3	46.62
4	51.62
5	54.81
6	55.81
7	51.40
Totals	51.16

Relation of the Length of the Incubation Period to Sex of Chicks

It is desirable to know whether the length of the incubation period is in any way associated with the sex of chicks. For purposes of study, table 2 was constructed to show the percentage of males obtained in the seven different emergent periods.

There is considerable evidence to indicate that the sex ratios were lower in the chicks hatched through the second third of the 21st day of incubation. Chicks emerging on the 22d day—periods 5, 6, and 7— showed a high sex ratio. The mean emergent period for all males was found to be 4.24, and for all females 4.09. The difference in these values is small and does not appear to be of any great significance.

The data tend, however, to substantiate the postulate that females predominate in the chicks emerging early and that males predominate in the chicks emerging later.

Relation of Length of Incubation Period to Viability

Mortality rates for the first six months of life may be taken as a measure of viability. These rates have been calculated for the first week, for one to four weeks, between four and eight weeks, from eight to twelve weeks, and from twelve weeks to housing time at about six months of age. Some chicks died on an unknown date during the first eight-week period without the sex being known, and are included as a separate group in the table. Total mortality for six months is also included. Table 3 gives the summarized results.

Mortality for the first four weeks showed essentially no relationship to the time of emergence from the shell. Between the ages of four and eight weeks, however, there appeared to be an important relationship between the length of the incubation period and mortality rate. During this period the chicks in emergent groups 1 and 2 showed no mortality; the chicks that hatched during the last two periods of the 21st day (groups 3 and 4) showed considerable mortality; and the chicks emerging in the last three periods, that is on the 22d day, showed excessive mortality.

There were 68 chicks missing at the end of the first eight weeks so that the age at death as well as the sex was unknown. These chicks were placed in their respective emergent period and the mortality recorded in the fifth line of the table. No relationship between emergent period and mortality rate was observed in this small group, except that the very late emerging chicks had a mortality rate of about 4.5 percent compared with about 1.5 percent for the chicks from the other emergent periods.

Mortality rates are recorded separately for the sexes after eight weeks. No consistent relationship between time of emergence and mortality rate appeared during the age period from eight to twelve weeks in either sex. Between twelve weeks and six months of age, males had a significantly higher mortality rate than females, but the relationship between time of emergence and mortality rate is not conspicuous if it exists at all. The data do seem to indicate that both males and females from the last emergent period were low in viability. The data in table 3 appear to indicate that chicks emerging late are very likely to exhibit low viability between four and eight weeks of age and not at other ages during the first six months.

The last line of the table records the total mortality to the age of six months, obtained by adding together the preceding mortality rates. The data indicate a consistent increase in mortality rate with each eight-hour increase in length of

the incubation period. This fact furnishes rather definite evidence that the early emerging chicks are the more viable.

TABLE 3. — NUMBER OF CHICKS AND PERCENTAGE MORTALITY BY EMERGENT PERIODS

	Emergent Period						
	1	2	3	4	5	6	7
Number of Chicks	15	166	970	1,978	1,151	355	126
Percent Mortality First Eight Weeks							
Sex Unknown:							
1st week	0	.60	.72	1.06	.70	2.25	4.76
Between 1 and 4 weeks	0	2.42	2.08	2.20	1.40	3.46	2.50
Between 4 and 8 weeks	0	0.00	1.06	1.93	2.66	5.37	4.27
Date unknown	0	0.00	1.61	1.44	1.37	1.89	4.46
Total	0	3.01	5.36	6.47	5.99	12.39	15.08
Percent Mortality Between Eight and Twelve Weeks							
Males	0	0	.76	.35	1.24	0	0
Females	0	0	.36	1.08	1.28	0	0
Both Sexes	0	0	.55	.68	1.26	0	0
Percent Mortality from Twelve Weeks to Housing (Six Months)							
Males	0	0.00	3.45	3.32	1.57	3.13	8.33
Females	0	3.13	1.79	2.84	3.03	1.35	4.76
Both Sexes	0	1.90	2.59	3.11	2.18	2.35	7.02
Total Mortality to 6 Months	0	4.91	8.50	10.26	9.43	14 74	22.10

Relation of Length of Incubation Period to Laying-House Mortality

A portion of the pullets produced was placed in the laying houses at about six months of age and trapnested for 365 days. No culling was done and the mortality rate from all causes was calculated for birds emerging during the different periods. The summarized data are presented in table 4.

The data indicate no relation between the time of emergence and mortality rate in females between the ages of six and eighteen months. It appears, therefore, that the length of the incubation period cannot be considered a criterion of future viability in the laying house.

Relation of Length of Incubation Period to Characters Affecting Egg Production and to Winter and Annual Egg Production

In the selection of pullets to be placed in the laying houses it is desirable to make use of every possible criterion of egg-laying ability. It was therefore considered advisable to test the relationship between the length of the incubation period in female chicks and certain fecundity traits, as well as winter and annual egg production.

TABLE 4. — RELATION OF LENGTH OF INCUBATION PERIOD TO LAYING HOUSE MORTALITY IN FEMALES FOR A 365-DAY PERIOD

Emergent Period	Total in Laying House	Died Within 365 Days	Percent Mortality
1	10	4	40.00
2	62	11	17.74
3	275	69	25.09
4	444	106	23.87
5	224	57	25.45
6	72	15	20.83
7	19	5	26.32

Body Weight at Six Months of Age

Females.—Heavy body weight in pullets when placed in the laying houses is desirable from the standpoint of large egg size and low mortality, according to Hays (1939). Furthermore, the experience of many practical breeders justifies the selection of larger pullets near the onset of sexual maturity. All pullets were weighed individually when they were placed in the laying houses at about six months of age. In table 5 are recorded the mean weights of pullets from the seven different emergent groups.

Mean body weights were almost identical for pullets in the different emergent groups. These data therefore indicate that the length of the incubation period does not affect body weight of pullets at six months of age.

Males.—Cockerels were weighed individually at six months of age, and the mean weights recorded according to emergent period, in table 5. The data indicate that cockerels hatched during the 21st day of incubation (periods 2, 3, and 4) were slightly heavier than cockerels hatched on the 22d day of incubation (periods 5, 6, and 7).

TABLE 5. — RELATION OF LENGTH OF INCUBATION PERIOD TO BODY WEIGHT AT SIX MONTHS

Emergent Period	Pullets		Cockerels	
	Number	Mean Weight Pounds	Number	Mean Weight Pounds
1	10	5.09	1	6.00
2	62	5.26	41	6.57
3	275	5.38	252	6.56
4	444	5.33	558	6.50
5	224	5.37	316	6.41
6	72	5.32	93	6.34
7	19	5.25	35	6.40

Body Weight at Sexual Maturity in Pullets

Body weight at sexual maturity is of considerable importance because sexual maturity marks the onset of the reproductive function. The mean weights of pullets in the different emergent groups are recorded in table 6. The pullets in the last five emergent groups were heavier than those of the two earliest groups, but there was no significant difference in body weight among the last five groups.

Table 6. — Relation of Length of Incubation Period to Body Weight and Age of Pullets at Sexual Maturity

Emergent Period	Number of Pullets	Mean Weight at First Egg Pounds	Number of Pullets	Mean Age at First Egg Days
1	9	5.67	9	187
2	57	5.76	57	183
3	257	5.96	261	192
4	409	5.98	412	193
5	195	6.06	196	197
6	60	6.05	60	197
7	17	5.99	17	202

Age at Sexual Maturity in Pullets

The stock used does not vary widely in age at sexual maturity because it closely approaches genetic purity for this character. Variations in age at first egg, when they occur, must therefore be attributed largely to environmental modifiers. For testing possible effects of length of the incubation period on mean age at first egg, the data are summarized in table 6.

It will be noted that the emergent groups were closely parallel in age at first egg and in mean weight at first egg; that is, the pullets from the two very early emerging groups averaged about ten days younger than those from the five later groups. These data indicate that age at sexual maturity is affectly slightly by the length of the incubation period.

Winter and Annual Egg Production

Winter egg production includes the number of eggs laid from first pullet egg up to March 1. In order to discover whether there is any relation between the length of the incubation period and subsequent winter egg production, the data are summarized in table 7.

There was a consistent decline in mean winter egg production as the length of the incubation period increased. There was a decline in mean winter egg production of about 30 eggs between the earliest emerging group and the sixth emergent group. These rather limited data indicate that the length of the incubation period bears an important relationship to subsequent winter egg production.

Annual egg production represents the number of eggs laid from first pullet egg for a period of 365 days. Available data are assembled in table 7 to discover possible relations between length of incubation period and annual egg production.

TABLE 7. — RELATION OF LENGTH OF INCUBATION PERIOD TO EGG PRODUCTION

Emergent Period	Mean Winter Production		Mean Annual Production	
	Number of Birds	Number of Eggs	Number of Birds	Number of Eggs
1	9	107	6	248
2	55	100	45	225
3	238	96	179	217
4	382	89	294	204
5	182	80	134	194
6	56	77	43	197
7	15	79	13	193

The data are rather limited, but they show a consistent decline in mean annual egg production as the length of the incubation period increased. There was a difference in annual egg production of about 55 eggs between the very early emerging pullets and the very late emerging pullets. In view of this fact, it would seem advisable for breeders to breed selectively for early emergence of chicks from the shell, and information regarding possible hereditary factors that may influence time of emergence would be very useful.

Annual Persistency

High persistency is vitally important from the standpoint of maximum egg production in any flock; hence it is desirable to ascertain whether persistency bears any relation to the length of the incubation period. Table 8 presents the mean persistency of birds in the seven different emergent periods.

A rather consistent decline in persistency may be observed as the length of the incubation period increased. There was a decline of about 25 days in the length of the production year in the birds of group 7 as compared with group 1. It seems probable, therefore, that earlier emerging birds are likely to be somewhat more persistent layers than late emerging birds.

TABLE 8. — RELATION OF LENGTH OF INCUBATION PERIOD TO ANNUAL PERSISTENCY

Emergent Period	Number of Birds	Mean Annual Persistency Days
1	6	362
2	45	350
3	179	344
4	294	338
5	134	330
6	43	334
7	13	336

Body Weight at the End of the First Laying Year

Heavy body weight at the end of the first laying year is important, according to Hays (1939). It serves as a general measure of how well each individual has survived a year of heavy laying. As a rule, those birds which fail to increase in body weight and those which actually decline in weight will give unsatisfactory hatching records the following spring as well as low egg records during the second year. In table 9 mean body weights at the end of the first laying year, at about eighteen months of age, are recorded for each emergent group. The absolute weight of a bird at this time may be used as something of a criterion of the bird's future value for breeding as well as for egg production.

Differences in mean weight between the emergent groups were small and bear no particular relationship to the time of emergence. It seems likely, therefore, that the length of the incubation period has no relation to body weight at the end of the first laying year.

TABLE 9. — RELATION OF LENGTH OF INCUBATION PERIOD TO BODY WEIGHT AT END OF FIRST LAYING YEAR

Emergent Period	Number of Birds	Mean Weight Pounds
1	6	5.63
2	51	6.19
3	199	6.39
4	328	6.29
5	162	6.28
6	54	6.26
7	14	6.07

Evidence on Inheritance of Length of Incubation Period

Since a large series of matings to test for possible inherited factors affecting length of incubation period has not been made, some evidence on this point may be gained from a study of the correlation between sires and sons and sires and daughters as well as between dams and sons and dams and daughters in length of incubation period. The constants arrived at from available data are given in table 10.

TABLE 10. — CORRELATIONS

	Number of Parents	Number of Offspring	Coefficient of Correlation	Correlation Ratio
Sires and Sons......	24	639	+.1686† ±.0259	
Sires and Daughters.	24	628	+.1080† ±.0266	.1737
Dams and Sons.....	108	518	+.1690† ±.0288	.2074
Dams and Daughters	108	474	+.2615‡ ±.0289	

†Not significant. ‡Definitely significant.

The limited data are not conclusive regarding possible inherited factors affecting the length of the incubation period. Sires and sons, sires and daughters, and dams and sons showed insignificant correlations in length of incubation period. Regression was non-linear between sires and daughters and between dams and sons. On the basis of 100 degrees of freedom, there was a significant correlation between dams and their daughters in length of incubation period. The meaning of this relationship is not clear. If dams transmit factors affecting the length of incubation period to their daughters, it is difficult to understand why such factors are not transmitted to their sons. It therefore seems logical to assume that the data are too meager to furnish satisfactory evidence on the inheritance phase of the problem.

SUMMARY

Data were secured during a three-year period on the length of incubation required by 4730 Rhode Island Red chicks. A study of possible relationship between length of the incubation period and sex, viability, and characters affecting fecundity led to the following deductions:

1. The length of the incubation period was not affected by weight of eggs in 430 dams studied.
2 Length of the incubation period was slightly shorter in the earlier hatches.
3. Length of the incubation period fluctuated over a period of about 56 hours during the normal hatching season.
4. Females predominated in the early emerging chicks.
5. Mortality rates for six months increased consistently as the length of the incubation period increased.
6. There was no relation between the length of the incubation period and the mortality rates for pullets in the laying houses between the ages of six and eighteen months.
7. No relation was shown between length of incubation period and body weight of pullets at six months of age.
8. Cockerels emerging early were slightly heavier at six months of age than late emerging ones.
9. There was no important relation between length of incubation period and body weight of pullets at sexual maturity.
10. Very early emerging pullets are likely to be slightly earlier in sexual maturity than late emerging ones.
11. More eggs before March first may be expected from early emerging pullets.
12. There was a consistent decline in annual egg production as the length of the incubation period increased.
13. Early emerging pullets are likely to be more persistent layers than late emerging pullets.
14. No relation was found between length of the incubation period and body weight at the end of the first laying year.
15. There was no conclusive evidence that the length of the incubation period is governed by inherited factors.
16. Selection of early emerging chicks appears to be of considerable economic importance.

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Natural Land Types of Massachusetts and Their Use

By A. B. Beaumont

This represents an attempt to supply certain technical information regarding soils considered essential as a basis for sound land-use studies and classifications.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

Upper: Profile View of Gloucester Soil, the most extensive upland soil in Massachusetts; important in dairy farming and fruit growing; typical of Land Type A1.

Lower: Landscape and Profile View of Hinckley, an outwash soil; one of the poorest agricultural soils of the State; best use, forestry or source of sand and gravel; Land Type B3.

NATURAL LAND TYPES OF MASSACHUSETTS AND THEIR USE

By A. B. Beaumont, Extension Soil Conservationist

Farmers have always recognized natural land characteristics as important factors governing land use; often, but not always, they are the determining factors of land use. Natural land characteristics fall into two general groups: permanent or fixed, and impermanent or transitory, depending upon whether they may be altered or modified by man acting directly or by natural forces directed by man.

Among the permanent land characteristics generally recognized as important in determining land use in New England are slope, elevation, texture and depth of soil, and nature of subsoil. To these is now added erodibility, or the capacity of a soil to erode, a soil characteristic heretofore not generally recognized in this section as of much importance in determining land use.

Impermanent land characteristics of importance in land use in New England include soil reaction, or the condition of the soil with respect to an adequate supply of lime; nutrient level, or state of fertility; and the nature and condition of the soil organic matter. Drainage and stoniness, two important land-use factors, may be considered permanent or impermanent, depending largely upon the economic aspects of modification.

It is the purpose of this bulletin, first, to report and interpret some data on natural land characteristics in relation to land use, and second, to present methods of land classification for use considered both applicable and practicable for Massachusetts conditions.

A Study of Natural Land Characteristics Affecting Land Use

In a study[1] of factors affecting land use in several towns of Worcester County, certain data concerning land characteristics were collected. Field mapping was done on a scale (1″=200′ or 1″=660′) sufficiently large to show areas as small as one-quarter acre. The information collected on the physical features is somewhat unusual in respect to the detail mapped, and is, therefore, valuable as a source of more precise knowledge of factors hitherto subject to rough estimate or opinion. Soil type, percent of slope, degree of stoniness, and character of erosion were mapped. Forty-eight soil types in seventeen correlated series and several provisional series, totaling 13,211 acres, were mapped. The soils mapped included one or more series in each of the principal topographic groups of the area studied. Summarized data are presented in tables 1 to 6.

Influence of Slope on Land Use (Table 1.)—In the area under consideration, where dairy farming is the major farm enterprise, pasture competes favorably with crops for the nearly level land (A slopes); 33.5 percent in pasture against 35.5 percent in crops. On all other slopes pasture has

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[1]A cooperative study conducted jointly by the U. S. Bureau of Agricultural Economics, the U. S. Soil Conservation Service, Harvard University, and Massachusetts State College. Data published in mimeographed form by the Massachusetts Extension Service as "A Statistical Study of Land-Use Data," Release No. 1 of Worcester County Land-Use Planning Project, December 1940.

the ascendancy, reaching a ratio of about 4 to 1 on C slopes and 6 to 1 on D slopes. Pasture competes effectively with woodland, the percentage devoted to pasture being greater on all slopes except B, where the figures are close.

Moderate slopes predominate on the land surveyed, as is indicated by the large acreages in A, B, and C slopes, B being the largest. The weighted average for all slopes, taking the mid-point of each slope range except D, and 30 for the D class, is 7.9 percent. However, it should be noted that these statements and the figure apply only to the farm land surveyed. More than half the land of Worcester County is not in farms, and much of this land has D slopes.

TABLE 1. DISTRIBUTION OF LAND-USE CLASSES IN EACH SLOPE CLASS.
(Acres and percentage given.)

Slope Class and Range in Percent		Cropland	Idle Land	Pasture	Woodland	Farm-yards and Urban Areas	Total
A (0-3)	Acres	1255.3	311.5	1186.3	769.2	18.5	3540.8
	Percent	*35.5*	*8.8*	*33.5*	*21.7*	*0.5*	*100.0*
B (3-8)	Acres	1363.3	160.6	1562.8	1612.9	32.0	4731.6
	Percent	*28.8*	*3.4*	*33.0*	*34.1*	*0.7*	*100.0*
BB (8-15)	Acres	884.5	107.0	1373.7	1116.6	22.7	3504.5
	Percent	*25.2*	*3.1*	*39.2*	*31.9*	*0.6*	*100.0*
C (15-25)	Acres	133.3	17.8	550.3	300.3	1.1	1002.8
	Percent	*13.3*	*1.8*	*54.9*	*29.9*	*0.1*	*100.0*
D (25+)	Acres	37.4	8.0	226.0	159.9	0.1	431.4
	Percent	*8.7*	*1.8*	*52.4*	*37.1*	*(1)*	*100.0*
Total area	Acres	3673.8	604.9	4899.1	3958.9	74.4	13211.1
	Percent	*27.8*	*4.6*	*37.1*	*30.0*	*0.5*	*100.0*

(1) Less than 0.1 percent.

Table 1 also shows the broad aspects of land use. Disregarding slopes, the distribution agrees fairly closely with that reported in the census of 1935. The cropland, according to the census, was 27.3 percent, which compares with 27.8 percent of this survey. There is more discrepancy in the figures from the two sources for pasture and woodland, which is due in part to the difficulty in separating pasture and woodland classes. The census reports a third separation, woodland pasture, and gives 43.3 percent for woodland pasture and "other" pasture, against 37.1 percent from the survey; it gives 23.3 percent woodland "not pasture", against 30.0 percent woodland found in the survey; and "other" land, 6.1 percent, which compares with 4.6 percent idle land and 0.5 percent farmyards and urban areas.

All the percentages in the preceding paragraph are based on the total farm land surveyed or, in case of the census, the total farm land of the county. Since the survey was made by the sampling process, no figures are reported for percentage of farm land in the county. The census gives 47.1 as the percentage of the total land area of the county in farms in 1935.

This figure combined with that of the survey gives 13.1 percent of cropland in the area, and combined with that of the census gives 12.8 percent.

Effect of Stoniness on Land Use. (Table 2).—Stoniness increased with all slopes. The lowest degree of stoniness was found on more than half of the A slopes; moderate stoniness was most abundant on the intermediate slopes, although slight and moderate stoniness were approximately equal on B slopes; and the fourth degree of stoniness was found on almost half the D slopes.

The significance of stoniness as a factor in land use is shown by the distribution of the different classes of stoniness in cropland. According to these figures, 92.2 percent of all the cropland fell in the first two classes, which are none or very slight and slight. A similar relationship is shown by a study of the situation on the Gloucester soils considered alone: 53.9 percent of the fine sandy loam and 85.9 percent of the loam were classed as cropland; whereas the corresponding figures for the stony phases of these types were 13.2 and 15.0. All these figures indicate that stoniness is a more important factor than slope in determining land use within the limits studied.

TABLE 2. DISTRIBUTION OF STONINESS CLASSES IN EACH SLOPE CLASS.
(Acres and percentage given.)

Slope Class and Range in Percent		Stoniness				
		None*	Slight	Moderate	Severe	Total
A (0-3)	Acres	1929.4	797.1	716.5	97.8	3540.8
	Percent	*54.5*	*22.6*	*20.1*	*2.8*	*100.0*
B (3-8)	Acres	1051.6	1626.7	1631.0	422.3	4731.6
	Percent	*22.2*	*34.4*	*34.5*	*8.9*	*100.0*
BB (8-15)	Acres	720.7	832.9	1521.6	429.3	3504.5
	Percent	*20.6*	*23.8*	*43.4*	*12.2*	*100.0*
C (15-25)	Acres	161.6	220.4	385.9	234.9	1002.8
	Percent	*16.1*	*22.0*	*38.5*	*23.4*	*100.0*
D (25+)	Acres	32.1	78.2	110.3	210.8	421.4
	Percent	*7.4*	*18.1*	*25.6*	*48.9*	*100.0*
Total area	Acres	3895.4	3555.3	4365.3	1395.1	13211.1
	Percent	*29.5*	*26.8*	*33.1*	*10.6*	*100.0*
Cropland	Acres	2320.3	1067.7	216.4	69.4	3673.8
	Percent	*63.2*	*29.0*	*5.9*	*1.9*	*100.0*

*None, or very slight.

Erosion, Erodibility, and Land Use.—The significance of soil erosion, and by implication, erodibility, is shown in tables 3, 4, and 5. First, it may be noted that second degree, or slight erosion predominated (84.0 percent, tables 3 and 4) and that moderate erosion was found on 12.1 percent of the total area surveyed. However, only 3.8 percent of the area showed no erosion, and only 0.1 percent showed severe erosion.

TABLE 3. DISTRIBUTION OF EROSION CLASSES IN EACH LAND-USE CLASS.
(Acres and percentage given.)

Land-use Class		Erosion				
		None Apparent	Slight	Moderate	Severe	Total
Cropland	Acres	94.7	3182.0	394.1	3.0	3673.8
	Percent	*2.6*	*86.6*	*10.7*	*0.1*	*100.0*
Idle land	Acres	81.3	441.3	80.4	1.9	604.9
	Percent	*13.4*	*73.0*	*13.3*	*0.3*	*100.0*
Pasture	Acres	190.5	3978.7	716.7	13.2	4899.1
	Percent	*3.9*	*81.2*	*14.6*	*0.3*	*100.0*
Woodland	Acres	138.1	3419.8	399.8	1.2	3958.9
	Percent	*3.5*	*86.4*	*10.1*	*(1)*	*100.0*
Farmyards and urban areas	Acres	0.0	71.8	2.6	0.0	74.4
	Percent	*0.0*	*96.5*	*3.5*	*0.0*	*100.0*
Total area	Acres	504.6	11093.6	1593.6	19.3	13211.1
	Percent	*3.8*	*84.0*	*12.1*	*0.1*	*100.0*

(1) Less than 0.1 percent.

TABLE 4. DISTRIBUTION OF EROSION CLASSES IN EACH SLOPE CLASS OF CROPPED LAND
(Acres and percentage given.)

Slope Class and Range in Percent		Erosion				
		None Apparent	Slight	Moderate	Severe	Total
A (0-3)	Acres	92.8	1154.5	8.0	0.0	1255.3
	Percent	*7.4*	*92.0*	*0.6*	*0.0*	*100.0*
B (3-8)	Acres	1.9	1299.4	62.0	0.0	1363.3
	Percent	*0.1*	*95.3*	*4.6*	*0.0*	*100.0*
BB (8-15)	Acres	0.0	678.9	205.1	0.5	884.5
	Percent	*0.0*	*76.8*	*23.2*	*(1)*	*100.0*
C (15-25)	Acres	0.0	42.5	88.7	2.1	133.3
	Percent	*0.0*	*31.8*	*66.6*	*1.6*	*100.0*
D (25+)	Acres	0.0	6.7	30.3	0.4	37.4
	Percent	*0.0*	*17.8*	*81.1*	*1.1*	*100.0*
Total area	Acres	94.7	3182.0	394.1	3.0	3673.8
	Percent	*2.6*	*86.6*	*10.7*	*0.1*	*100.0*

(1) Less than 0.1 percent.

The relationship of erosion to land use is shown by tables 3 and 4. With the exception of the idle land, the acreage of which was so small as to throw doubt on the value of deductions based on it, the percentages of the land-use classes in the erosion classes are fairly uniform (table 3). Cropland had the lowest percentage showing no erosion, slightly more than pasture and woodland showing slight erosion, and next to the least amount of severe erosion. Severe erosion was percentually very small in all classes. Moderate erosion was most abundant on pasture land.

It is difficult to interpret erosion in this area in terms of land use because of marked and continuous changes in land use since 1880. Much land now in permanent pasture or woodland was previously cropped. Soils actively eroded at the peak of agricultural development have in many cases become stabilized by grass or forest cover, but the evidence of erosion still exists. This doubtless accounts largely for the uniformity of the figures under the different types of land use. Also, since erosion has been, and is, only slight to moderate, as a factor determining land use it was outweighed by the more significant factors of slope and stoniness; or at least these factors were apparently considered more significant by the farmer.

In the survey, sheet erosion was found to be by far the most common and extensive type. Occasional gully erosion was mapped on 17.9 acres, or 0.13 percent of the area. For practical, interpretative purposes, this class was thrown in with moderate erosion in this study. The damage caused by sheet erosion is less obvious to the average farmer than is that due to gullying, and can to some extent be counteracted by a generous use of soil supplements. These facts probably account to a considerable degree for the apparent unimportance of erosion as a factor influencing land use.

TABLE 5. DISTRIBUTION OF EROSION CLASSES IN EACH SLOPE CLASS.
(Acres and percentage given.)

Slope Class and Range in Percent		Erosion				
		None Apparent	Slight	Moderate	Severe	Total
A (0-3)	Acres	489.0	3043.5	8.3	0.0	3540.8
	Percent	*13.8*	*86.0*	*0.2*	*0.0*	*100.0*
B (3-8)	Acres	12.4	4570.9	148.3	0.0	4731.6
	Percent	*0.3*	*96.6*	*3.1*	*0.0*	*100.0*
BB (8-15)	Acres	2.8	2899.1	602.0	0.6	3504.5
	Percent	*0.1*	*82.7*	*17.2*	*(1)*	*100.0*
C (15-25)	Acres	0.4	513.2	482.5	6.7	1002.8
	Percent	*(1)*	*51.2*	*48.1*	*0.7*	*100.0*
D (25+)	Acres	0.0	66.9	352.5	12.0	431.4
	Percent	*0.0*	*15.5*	*81.7*	*2.8*	*100.0*
Total area	Acres	504.6	11093.6	1593.6	19.3	13211.1
	Percent	*3.8*	*84.0*	*12.1*	*0.1*	*100.0*

(1) Less than 0.1 percent.

Interrelationships Between Certain Land Characteristics

Slope and Erosion.—More striking than the relation between erosion and land use is that shown between the degree of erosion and slope of land. Table 5 shows that there was definite and continuous increase in the severity of erosion with the increase in steepness of slope, excepting the first two classes of erosion on B slopes. On A slopes 99.8 percent of the total land, and on B slopes 96.9 percent had no erosion or slight erosion. C slopes were about evenly divided between no or slight erosion on the one hand and moderate or severe erosion on the other. On D slopes 84.5 percent of the land had moderate or severe erosion.

Soil Type and Erosion.—The data of the survey were not sufficient to permit a study of the soil type as a factor in erosion. The next unit of classification above the type is the series. Table 6 shows the distribution of erosion in certain soil series. It is to be noted that, with the exception of the Hinckley series, the erosion mapped was almost wholly slight or moderate with little difference among series. With the small acreages represented in all series except Gloucester, the figures should be considered indicative rather than conclusive. The comparatively high percentages of moderate and severe erosion of the Hinckley soils is in accordance with general field observations. This series is characterized by rather sharp slopes and soil poorly adapted to grasses.

TABLE 6. DISTRIBUTION OF EROSION CLASSES IN CERTAIN SOIL SERIES.
(Acres and percentage given.)

Soil Series		Erosion				
		None Apparent	Slight	Moderate	Severe	Total
Gloucester	Acres	11.1	3845.9	704.0	3.1	4564.1
	Percent	*0.2*	*84.3*	*15.4*	*0.1*	*100.0*
Sutton	Acres	17.9	905.9	148.9	0.0	1072.7
	Percent	*1.7*	*84.4*	*13.9*	*0.0*	*100.0*
Brookfield	Acres	0.0	640.1	63.4	0.6	704.1
	Percent	*0.0*	*90.9*	*9.0*	*0.1*	*100.0*
Charlton	Acres	0.0	1122.3	87.1	0.0	1209.4
	Percent	*0.0*	*92.9*	*7.1*	*0.0*	*100.0*
Merrimac	Acres	0.0	870.1	74.3	0.0	944.4
	Percent	*0.0*	*92.1*	*7.9*	*0.0*	*100.0*
Hinckley	Acres	0.0	232.5	479.9	15.6	728.0
	Percent	*0.0*	*31.9*	*66.0*	*2.1*	*100.0*

Additional Factors Affecting Land Use

Other natural factors important in determining land use are those affecting soil moisture, and, to a less extent, the chemical characteristics of the soils. These factors are more or less definitely associated with soil type, but there are also significant variations within the soil types. Factors

affecting soil moisture and chemical characteristics were not specifically treated in the survey reported, but they will be discussed briefly here.

Most Hinckley soils are excessively drained and, therefore, are subject to drouth. They are also low in native available plant food. Because of these characteristics the use of Hinckley soils for agricultural use is hazardous. Poorly drained soils have very limited agricultural use. Soils of this nature having definite characteristics are given special series designations, such as Whitman. Gloucester fine sandy loam generally has medium moisture relations, being neither poorly nor excessively drained, but there are exceptions to this.

Massachusetts soils have been developed under a cool, humid climate, and are, therefore, generally deficient in available bases, particularly in the upper layers. This is a characteristic which to some extent affects land use but more generally affects the practice followed after the choice of use has been made. It is generally necessary to add lime and fertilizer supplements to Massachusetts soils for successful cropping. Some soils require more of these supplements for a given crop than do others, and there is also a difference in crops in their requirements for lime and fertilizer.

Classification of Land for Use

There are many methods for the classification of land, and the objectives in land classification are numerous and varied. Any method which accomplishes the purpose for which it was intended may be called good. Agronomists and others interested in land use seek a method of land classification which has practical application and is developed on a scientific basis, but is not so technical as to require a trained technician for its interpretation or application.

The classification of land according to soil type has received a wider application in the United States than any other method which has had agricultural use as its objective. Massachusetts has been entirely surveyed as to soil type, and there is much valuable information regarding soils and their use in the reports of the survey. These surveys have been made at considerable cost to the State and Federal Governments. Therefore, any method of land classification which can be based largely or wholly on the soil survey has certain obvious advantages over others which make little or no use of this survey.

In the past the fullest use possible has not been made of the information supplied in the reports and the maps of the soil survey, by those without special training in soil technology. This has been due partly to the lack of technical training by those having need of the information, and partly to the failure of those who wrote the reports to make the necessary interpretation of their findings. Soils have recognizable morphological characteristics which make it possible for a good soil surveyor to differentiate types which, though perhaps highly significant from a pedological viewpoint, have little or no significance from the standpoint of agricultural use. Soils may well be subdivided in great detail for scientific purposes, and then recombined into groups, or land types, for practical utility.

Possibly in the light of future research the significance of certain soil characteristics not now understood may be discovered. Consider, for example, the Gloucester and Brookfield soils. These series have very similar characteristics related to topography, stoniness, erodibility, soil

moisture, and content of lime and the common plant nutrients. They differ in color and the content of easily soluble iron, both of which are due to differences in the parent rock material of the two series. These series are at present used for the same types of farming with about equal success. It is not thought that the color difference is or will be found to be significant from the standpoint of use. The difference in content of available iron may be significant, particularly from the standpoint of producing crops of high iron content and therefore of greater therapeutic value in preventing anemia in man or beast.

Natural Land Types

Of the many methods which have been proposed for classifying land for use, one of the most useful and practicable is that based on the natural land type.[2] A natural land type is defined as a body of land having a given set of physical, chemical and biological characteristics. In its simplest form a land type may be identical with a soil type or a phase of a soil type. It may, and usually does, comprise two or more soil types or phases of them; it may even cut across soil types. It meets the need for a unit of land which is broader than the soil type, is more restricted than the soil group, and is capable of areal delineation. A good soil survey is an excellent basis for a land-type classification, but it is not indispensable; land types can be mapped directly in the field.

Natural land-type classification is being developed in connection with county land-use planning work in Massachusetts. This classification is essentially an interpretation of the soil survey in terms of land use. It simplifies the soil survey, puts the valuable and extensive information contained in it into a form which can be readily understood by those not trained in soil technology, and reduces the number of land units to a workable number. In Essex County 50 soil types were reduced to 13 land types. Soil types or their phases having closely similar natural characteristics are grouped together to form land types. Provided no soil type is divided between or among land types, the land-type map is as accurate as the soil-type map from which it is made. In placing the soil types in land-type categories it is usually necessary to supplement the information given in the soil survey with some field work.

The land-type classification as developed in Massachusetts is useful especially in large-scale, or area, land-use planning. The scale on which the maps are made is 1:62,500 (approximately 1 inch to the mile), which is the same as that of the soil-type map. This scale is not large enough for detailed land-use planning on individual farms, but can be used with facility for such large-scale planning as locating areas suitable for certain types of farming, delineating areas unsuited to farming, and determining or analyzing causes of problem areas. An example of a natural land-type classification is that developed for Essex County, given in table 7.[3] This kind of land classification can be developed for each county of the State. Rarely will the outline for any county be found entirely applicable to another; each county must be considered individually.

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[2]Beaumont, A.B. The natural land type in land-use planning. Southwest. Soc. Sci. Quart. 18 (3):231-234 (1937).

[3]This classification was developed with the assistance and cooperation of Francis C. Smith, County Agricultural Agent, and Alton G. Perkins, Instructor in Soils, Essex County Agricultural School.

This classification is based in part on principles established by the study of natural land characteristics reviewed above. The categories were selected and defined so that information given in the soil survey reports could be used to the best advantage. It will be noted that the major groups are based on positional and topographic relationships, as uplands and lowlands. Slope, stoniness, and drainage are given considerable weight; and the several factors determining soil type such as profile arrangement, texture, and content of organic matter are considered. The non-agricultural group (E) is composed of all land types not suited to agriculture for various reasons including rough topography, excessive stoniness, and high susceptibility to drouth. This classification states the types of farming, but not the specific crops, to which the land types are adapted; and it broadly prescribes methods of soil conservation necessary.

Use Capabilities of Land

In planning land-use activities for individual Massachusetts farms a scale much larger than that used in making the county soil maps is necessary. The United States Soil Conservation Service has developed technics for mapping farms and planning land use which are being applied effectively in this State. The scale of 1:7920 (8 inches to the mile) is being used. First, a map is made showing soil type, physical characteristics of land, and erosion. With this as a basis a second map showing recommended practices of land use is then made.

As a further aid to land-use planning, the Soil Conservation Service has developed a system of land classification based on land-use capabilities. "Classes of land according to use capability are based on the physical land factors together with their environment and expressed in terms of the restrictions in use or practices and measures necessary for the most intensive utilization that is consistent with the preservation of the soil and its plant cover. Eight classes of land according to use capability are now recognized. The classification is national in scope, designed to meet the conditions throughout the country. . . . Seldom, if ever, will all eight classes be represented in one area."[4]

For Massachusetts conditions six categories of this classification appear to be sufficient. They are as follows:

A. Suitable for cultivation
- I. Without special conservation practices.
- II. With simple conservation practices.
- III. With complex or intensive conservation practices.
- IV. Suitable for occasional or limited cultivation.

B. Not suitable for cultivation.
- Vg. Suitable for permanent grassland.
- Vw. Suitable for woodland.

In order to show the applicability of this method of classification to Massachusetts conditions the soil types of Essex County have been arranged according to their use capabilities, which are given in table 8.

[4]From Field Memorandum S.C.S. No. 848-B, Sept. 28, 1940.

TABLE 7. NATURAL LAND TYPES OF ESSEX COUNTY, MASSACHUSETTS

A. Uplands derived from glacial till; topography undulating to hilly.

1. Soils of medium texture, good drainage, and few stones; best soils of A group. Suitable mainly for general farming, dairying and orcharding; selected small areas good for market gardening and small fruits. Slopes average about 6 per cent; erosion control measures generally necessary; simple measures such as strip cropping and contour planting usually sufficient; some land too steep for successful cultivation.
    - Gloucester loam
    - Gloucester fine sandy loam
    - Gloucester fine sandy loam, gravelly phase
    - Coloma loam
    - Coloma fine sandy loam
    - Charlton loam
    - Charlton loam, gravelly phase
    - Brookfield fine sandy loam
    - Hollis fine sandy loam
    - Woodbridge fine sandy loam

2. Same as A 1, except subsoils or substratum more compact; best suited to general and dairy farming; in favorable cases also orcharding, small fruits and market gardening. Slopes average about 4 per cent; much of the area can be cultivated without special erosion controls.
    - Woodbridge loam
    - Essex fine sandy loam
    - Essex fine sandy loam, gravelly phase
    - Sutton loam

3. Same as A 1 or A 2 except containing enough stones or ledge to interfere with cultivation; best suited to pasture or woods; also good for poultry raising. Slopes average about 8 per cent; strip-cropping and contour planting generally suffice for erosion control on cultivated land; permanent pasture or woods most common.
    - Gloucester stony loam
    - Gloucester very stony loam
    - Gloucester stony fine sandy loam
    - Brookfield fine sandy loam, stony phase
    - Hollis fine sandy loam, stony phase
    - Woodbridge loam, stony phase
    - Woodbridge fine sandy loam, stony phase
    - Hinsdale stony fine sandy loam
    - Essex fine sandy loam, stony phase
    - Coloma fine sandy loam, stony phase

B. Land at intermediate levels, derived from terraces, glacial outwash material; topography level to hummocky; drainage generally good to excessive.

1. Soils of medium texture; level to undulating; free from large stones; organic matter and natural fertility low, slightly to somewhat subject to drouth; best soils of B group; best suited to intensive farming, especially market gardening; also good for poultry raising. Slopes of Merrimac soils average about 2 per cent; much of this type requires no special erosion control methods; slopes above 2 per cent require contour planting, strip cropping, or terracing. Slopes of Wenham soils average about 6 per cent; terraces are generally necessary under intensive cultivation. Winter cover crops are especially necessary on this type to check losses by leaching.
    - Merrimac fine sandy loam
    - Merrimac loam
    - Wenham fine sandy loam

2. Same as B 1 except of coarser texture and more subject to drouth; uses similar to B 1. Slopes average about 2 per cent; no special erosion control methods necessary on much of this type; cover crops especially necessary to check leaching and supply organic matter.

Merrimac fine sandy loam, gravelly phase
Merrimac sandy loam
Merrimac sandy loam, gravelly phase

3. Soils of medium to coarse texture, hummocky topography, and excessive drainage; subject to drouth; best suited to woods, but favored areas may be used for pasture or early market garden crops; also good for poultry raising. Extensively used for sand and gravel supplies. Slopes average about 6 per cent; when cultivated, complicated erosion control methods are usually necessary.
   Hinckley gravelly sandy loam
   Hinckley gravelly sandy loam, dark colored phase
   Hinckley gravelly loam

C. Lowlands derived from low terraces and recent alluvium; topography level to undulating.

1. Soils of medium to fine texture, level to slightly undulating; first bottom and low terraces; good for dairy farming, market gardening and small fruits; drainage needed in some cases; slopes average about 1 per cent; special erosion control methods rarely necessary.
   Orono fine sandy loam
   Ondawa very fine sandy loam

2. Soils of fine texture; level to slightly undulating; terraces; good for dairy farming and in some cases market gardening and small fruit; drainage needed in many cases. Slopes average about 1 per cent; special erosion-control measures rarely necessary.
   Orono silt loam
   Orono silt loam, stony phase
   Palmyra loam

D. Poorly drained land requiring artificial drainage for agricultural use; texture and organic matter variable.

1. Soils high in organic matter; in some places potentially valuable for dairy farming and truck crops. Level or nearly level; erosion control methods may be necessary in rare instances on Whitman soils.
   Whitman loam
   Muck
   Peat

2. Soils of medium to low organic matter subject to overflow; best use pasture or hay; some non-agricultural. Level or nearly level; surface erosion control rarely necessary; control of stream-bank erosion occasionally necessary.
   Meadow
   Tidal marsh

E. Land of little or no agricultural value; best suited to forest, recreation, wild life preserves, building sites, etc. Erosion control rarely necessary because of permanent natural cover or buildings.

1. Soils of coarse texture, level to hummocky topography, and strongly subject to drouth; low in organic matter and available plant food.
   Gloucester stony loamy sand
   Hinckley gravelly sandy loam, stony phase
   Merrimac loamy sand
   Hinckley loamy sand
   Coastal beach

2. Land of very rough topography, very stony or ledgy.
   Rough stony land

3. Filled areas of miscellaneous origin.
   Made land

Table 8. Soil, Slope, and Erosion Grouping for Land-use Capability Classes in Essex County, Mass.

Land Type* or Soil Group	Slope Classes**	Erosion: None to Slight	Erosion: Moderate	Erosion: Severe	Erosion: Very Severe
A 1	A	I	II	....	....
	B	II	II	III	....
	BB	III	III	IV	IV
	C	IV	IV	Vg	Vg
	D	Vg	Vg	Vw	Vw
A 2	A	I	II	....	....
	B	II	II	III	....
	BB	III	III	IV	IV
	C	IV	IV	Vg	Vg
	D	Vg	Vg	Vw	Vg
A 3	A	IV	IV	....	....
	B	IV	IV	Vg	....
	BB	IV	Vg	Vg	Vw
	C	Vg	Vw	Vw	Vw
	D	Vw	Vw	Vw	Vw
B 1	A	I	II	III	....
	B	II	II	III	III
	BB	III	III	IV	IV
	C	IV	IV	Vg	Vg
	D	Vg	Vg	Vg	Vw
B 2	A	I	II	II	....
	B	II	II	III	III
	BB	III	III	III	IV
B 3	BK	II	II	III	....
	BBK	III	III	IV	Vw
	CK	IV	IV	Vw	Vw
	DK	Vw	Vw	Vw	Vw
C 1	A	I	II	....	...
	B	II	II	III	....
C 2	A	I	II	....	....
	B	II	II	III	....
	BB	III	III	IV	....
D 1	A	IV	IV	....	....
	B	IV	IV	....	....
D 2	A	IV	....	....	....
E 1	A	Vw	Vw	Vw	Vw
	B	Vw	Vw	Vw	Vw
	BB	Vw	Vw	Vw	Vw
	C	Vw	Vw	Vw	Vw
	D	Vw	Vw	Vw	Vw
E 2	A	Vg	Vg	....	....
	B	Vg	Vg	Vw	....
	BB	Vw	Vw	Vw	Vw
	C	Vw	Vw	Vw	Vw
	D	Vw	Vw	Vw	Vw
E 3	A	I	II	....	....
	B	II	III	III	....

*The land types indicated by the letters and figures below are described in table 7.

**For percentage range of slope classes, see table 1. K=very uneven, usually hummocky, land.

Discussion of Natural Land Types of Massachusetts

First, consider the major groups of land types. Most counties of Massachusetts will be found to have the largest acreage in the group (A, table 7) composed of well-drained upland soils derived from glacial till, and the land (B group) lying at intermediate levels comes second in amount. The C and D groups are relatively small in all counties in the State. In Barnstable County the acreage of alluvial soils is so small that it may well be combined with the C and D groups. In all counties the last group (E in Essex County), or land of little, or no, agricultural value, is relatively large, either because of the large amounts of rough stony land and/or of poor grades of Hinckley or Plymouth soils.

The breaking down of the major groups into categories significant in land use is more difficult than the first division. Variations within the soil series, even within the type, account for some of this difficulty. Stony types and phases are usually put in the agricultural group on the assumption that they may be used for pasture. However, some portions of these soils are too stony for good pasture, and a further breakdown into degrees of stoniness would serve as a basis for throwing portions of the stony soils into the non-, or low, agricultural group. The B group is somewhat easier to differentiate into land types significant in land use because of marked differences in Merrimac and Hinckley soils. There is more difficulty in subdividing the C and D groups.

This classification does not permit a consecutive numbering of land types with respect to their agricultural value—a type of classification or rating often requested, and one that would have obvious advantages. A land type or soil type is poor, good, better, or best, only with reference to a particular use, characteristic, or condition. For example, that which is naturally good for vegetable growing may be poor for dairy farming, or for forestry or recreational purposes; and first-class land for dairy farming is valueless for cranberry growing. This classification does, however, permit some comparative evaluation of land types within the groups, and this has been pointed out where it is well defined. Upland soils free of, or low in, stones are the best of that group for general farming and dairying, and the nearly level outwash soils of medium texture (B1) are the best for market gardening.

Finally, it is to be pointed out and emphasized that this classification is based on natural land characteristics. In its practical application it must be used in connection with other factors affecting land use, particularly economic and social factors. Unique advantages of location, for example, may outweigh certain natural limitations. Land poorly adapted to a given crop because of low fertility and poor water-holding capacity, may be made productive by the use of large amounts of commercial fertilizers and the use of irrigation water. All such factors must be taken into consideration in determining the best use of a given piece of land.

This classification and its interpretation have emphasized use of land for agriculture or forestry; but in a state such as Massachusetts, urban, industrial, and recreational uses assume great importance and cannot be ignored. Much of the non-agricultural group and the poorer types of the A and B groups are highly valuable for such uses. Some fine residential sections are located on rough stony land, and this type is excellent for certain kinds of recreation. Most of the gravel pits of the State

are found in the Hinckley soils of the B3 group. Unfortunately, due in some cases to poor planning or in most cases to lack of planning, a considerable amount of good agricultural land has been taken for urban and industrial uses. Some readjustments in use may be possible; future planning should take more cognizance of natural adaptability.

Summary

Data on certain natural characteristics of land important in determining its use were collected from 48 soil types in 17 series on 13,211 acres. Soil type, slope, stoniness, and erosion were mapped in great detail, which permits comparisons and interpretations hitherto impossible in this area. Slope was shown to be an important factor affecting land use in dairy farming, but stoniness was more important. Erosion was found to be extensive, only 3.8 percent of the area surveyed showing no erosion, but slight erosion was by far the predominant type.

Any method of land classification which accomplishes the purpose for which it was intended may be called good. A method of land classification which is not so technical as to require a trained technician for its interpretation or application is sought by certain groups interested in land use. Soil type is one of the important factors determining land use, but it is not considered the most practicable unit for this purpose. Soil types may be grouped into natural land types for practical utility.

The classification of land into types based on natural characteristics and for purposes of utilization is illustrated by means of the categories set up for one county. This classification is of value especially in connection with large-scale planning. It is based on the information given in the soil surveys of the State and a small amount of field work. Since this classification is a natural one, it must be applied in connection with economic and social factors.

For detailed land-use planning, as on individual farms, the technic and classification involving land use capabilities developed by the United States Soil Conservation Service has certain advantages. An example of the application of the method of classifying land according to its use capabilities is given.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

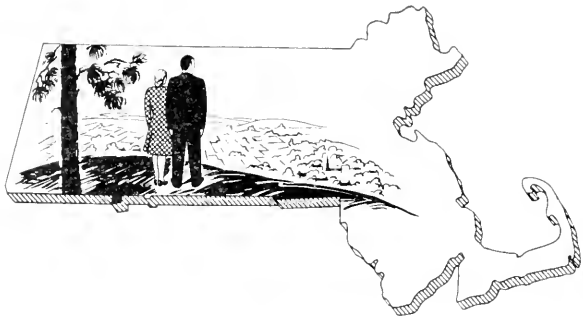
Bulletin No. 386 December 1941

Rural Youth in Massachusetts

By Gilbert Meldrum and Ruth Sherburne

National concern regarding the general welfare of our population deserves some planning, for which studies of this sort may furnish a basis.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.



RURAL YOUTH IN MASSACHUSETTS[1]

By Gilbert Meldrum[2] and Ruth E. Sherburne,
Research Assistant in Economics

Twenty years ago, in 1921, more children were born to American parents than in any other year, before or since. Today, in 1941, those children and the others born in the years immediately before and after 1921, are young men and women — the "older youth." Greater in number than ever before, they represent a significant segment of our population; the kind of people they are will have a profound effect on the kind of business and industry, religion and government the country is to have in the years to come.

These young people were born during or just after the first World War, lived through a great depression, and emerged as adults in the face of a second world conflict. Their problems, their needs, and their opportunities are to a large extent the responsibility of young and old alike. Rural policy committees in Massachusetts, as in several other States, have recognized this responsibility and accepted its challenge. They realize that a well-rounded and continuing program for the welfare of rural people should include plans for rural youth.

The study described in this report was made at the request of these rural policy committees and had two purposes: (1) To gather and analyze information on the resources, the problems, and the opportunities of rural youth in Massachusetts; (2) to create interest among the young people themselves to furnish assistance in the recognition and solution of their problems.

To do these things effectively, the work was planned so that rural young people would have a part in it from the beginning. Most of the field work was done by volunteers in the 4-H Service Clubs. In selected rural towns in four counties, the field workers made a house-to-house survey in an attempt to interview all boys and girls between the ages of 16 and 25. In addition, boys enrolled in vocational agriculture schools and girls taking vocational agriculture and home economics courses in these counties were interviewed. In all, nearly 600 questionnaires were filled out.

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[1]The general plan for this project and guidance in the collection and analysis of the data were provided by Dr. David Rozman, Research Professor of Economics, Massachusetts Agricultural Experiment Station; and by Dr. O. E. Baker, Walter C. McKain and C. R. Draper of the Bureau of Agricultural Economics, United States Department of Agriculture. Grateful acknowledgment is made to individuals in the Massachusetts Extension Service for their assistance in the study, and to the young people in various towns for their enthusiastic participation in the field work.

[2]Junior Sociologist, Division of Farm Population and Rural Welfare, Bureau of Agricultural Economics, United States Department of Agriculture.

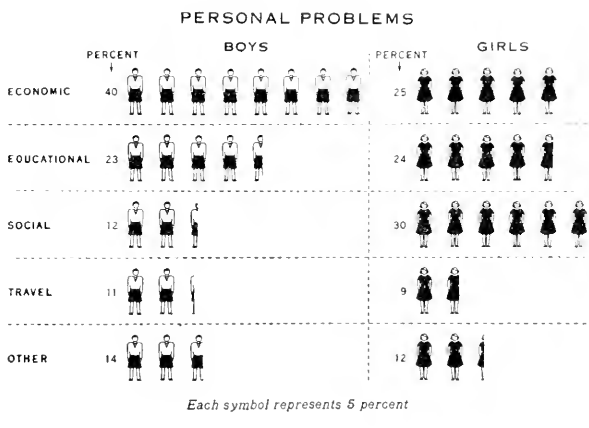
The Problems of Rural Youth

In order to discover the most important needs of the young people, interviewers asked each to select from a list of 13 personal problems the two that he or she found most pressing. Their answers are summarized in figure 1.

Economic problems were listed most frequently by the boys. Two out of every five responses had to do with making a living, finding a job, or getting started in farming. One-fourth of the problems listed by the girls also had to do with economic welfare. For the total group of young people economic problems outweighed any other.

Next in importance was the need for more education and for vocational guidance. One-fourth of the problems of the boys and girls had to do with education. This emphasis upon economic and educational problems reflects a seriousness not generally attributed to young people. But it must be remembered that the last depression struck these young people at an impressionable age. The sobering effect of the depression years is indicated in their present attitudes.

Figure 1



Personal needs considered most outstanding by the girls may be grouped under the heading "social." Twenty-nine percent of their responses were concerned with knowing more young people, developing their own personalities, and enjoying more entertainment. For boys, on the other hand, social opportunities did not seem so significant, or perhaps were thought unworthy of male consideration.

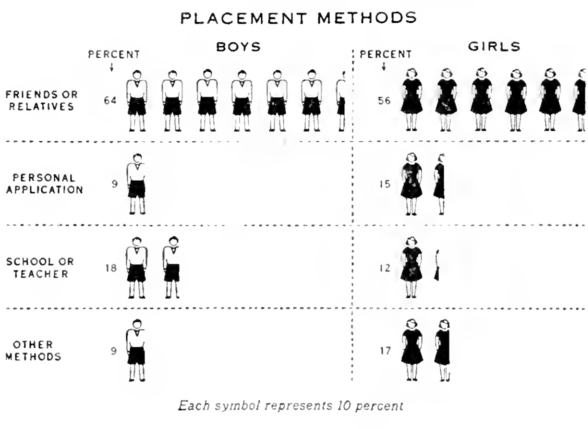
One out of five of these young people checked "opportunity to travel" as one of their major problems. The significance of this item is difficult to measure, and probably depends upon when and why the desire to travel comes to the front before the various economic, educational, and social problems. A partial explanation may be found in the quest for new experience; but, more likely, the prevalence of this desire for travel represents a degree of discontent and dissatisfaction which these young people feel in their home communities, and from which they vaguely wish to break away.

The Employment of Rural Youth

Practically all of the boys and girls who were out of school were employed last year. Only one of the boys and eight of the girls were unemployed for the entire year. Not all the jobs were full-time and many of the full-time jobs were of brief duration. This indicates that underemployment rather than unemployment is the most serious problem of these young people. As part-time jobs and summer employment are significant for rural youths of all ages, vocational and other educational training should be adapted to meet these needs.

Opportunities to find employment varied greatly among the local communities studied. In towns adjacent to urban centers such as Worcester, New Bedford, Taunton, Attleboro, and Pittsfield, chances for off-farm employment were greater. In the more isolated farming communities considerable variation was found in the number of available farm jobs, either at home or on farms away from home, and in the average rates of pay for farm work. These differences were reflected in the varying degrees to which the young folks wanted to leave their home communities. The girls, for example, were more anxious to get to the city, because they had fewer chances for rural employment than the boys.

Figure 2



Apparently only the most meager placement service was available for these young people. Two-thirds of the boys and more than half of the girls obtained their jobs through friends or relatives. A fifth were placed by school teachers and about the same proportion obtained their jobs by personal application. Vocational agricultural schools provided a fairly effective placement service for their students. Although much can be said for the spirit of individualism that it undoubtedly fosters, this reliance upon a small circle of friends and acquaintances can not best serve the placement needs of the majority of boys and girls in a community. Obviously considerable attention should be given to the placement question, as a young person's first job frequently determines his lifework.

Most of these young people were dissatisfied with their present employment and only one-fourth believed their jobs afforded opportunities for advancement. One possible explanation lies in the small incomes they received. Only six youths

(boys) earned more than $1,000 during the year preceding this study. Of the boys in school (but not in vocational training schools), half made less than $100; the rest, between $100 and $400. The girls in school earned even less. Three out of five earned nothing, and 87 percent of the remainder reported an income of less than $100.

Of the boys not in school, a third earned less than $200; another third, between $200 and $600; and the remainder, something over $600. For the out-of-school girls, $800 seemed to be the maximum income toward which anyone could aspire; only one received more than this amount during the year.

Most of the jobs wanted by these young people were well within the limits of possible achievement. Nearly all the boys in vocational agricultural schools were looking, quite naturally, to farming and related occupations for a lifework. Of the rest, more than half wanted work in agricultural or mechanical trades. Sixteen percent of the boys in school, and 5 percent of those out of school had expectations of becoming professional men.

Ambitions of the girls still in school were somewhat higher than those of the girls whose formal education was completed, perhaps because those in the latter group realized that further training for them was unlikely. Principal occupational choices of the school girls were clerical and secretarial work, nursing, and teaching. Less than a fifth chose homemaking. Of the girls not in school, nearly one in four gave homemaking as her choice, and one in five chose clerical or secretarial work. Such occupations as mill work, domestic help, and salesgirl were listed frequently by this group of girls, but not at all by those in school.

Both boys and girls apparently were vague as to the requirements of their chosen occupations and the difficulties of getting started in them. But the ones who were in school showed more optimism than those out of school regarding the chances of getting the jobs they wanted. This emphasizes the need, already sensed by the young people, for vocational guidance adapted to their situation.

Of the boys planning to enter into farming, most of those who answered the question indicated that savings from wages would furnish the necessary capital. Although some boys mentioned working on other farms, the majority regarded a factory job as the best method of getting started. They planned to start out in a small way and continue on a part-time basis.

The Education of Rural Youth

From responses given by these rural youths to the questions concerning education, it was possible to obtain a description of their opportunities for formal education, some measure of the degree of satisfaction derived from their schooling, and some idea as to their plans and needs for the future.

Most of the young people had some high-school training. Those still in school numbered 386, and of these 4 were in grammar school, 6 in post-high-school business training, 10 in college, and the rest in high or vocational schools.

About half of the 175 out-of-school boys and girls had the equivalent of a high-school education. Only four had attended college. The remainder had completed grammar school and in some instances one or more years of high-school training. It should be remembered that only young people still living in rural areas were studied and that a disproportionate number of high-school and college graduates may have left their home towns.

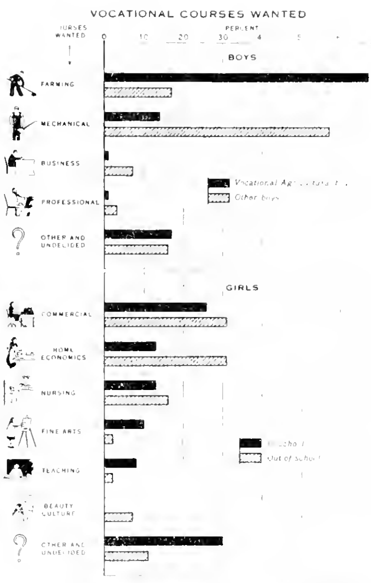
To the question "Do you think your schooling has helped or will help you to get ahead?", 92 percent of the boys, and 88 percent of the girls answered "yes."

When asked how education had helped them, answers were vague, but three out of five indicated that the main thing these boys and girls gained from their education was either general knowledge or the social prestige that comes from having been to school. Most of the other answers mentioned directly some specific skill acquired in school, and several stated that vocational guidance was the chief way in which their education had helped them.

In general, these boys and girls appeared to be satisfied with what their education had done for them. None of the boys mentioned what their education lacked, although six girls noted that their schooling had not prepared them to do anything.

Half of the young people—50 percent of the boys, and 46 percent of the girls—said they did not plan to go to school (or back to school) the next year. In general, those in school were much more certain of entering the next year, than those out of school; and in general, the schoolgirls showed more inclination to continue in school than did schoolboys. Three-fourths of the girls and two-thirds of the boys in school planned to continue the next year.

Figure 3



Of the youths who did not plan to return to school, not all were staying out from choice. One-fourth of the boys and girls indicated that they wanted to go to school the next year, but would be unable to attend. Lack of money, and the necessity of working were mentioned frequently as reasons.

Practically all of the reasons given for continuing in school showed a strong desire on the part of these young people for specific vocational training. They were dissatisfied, in other words, when high schools did not provide such training, and their desire for more education was concerned mainly with the chances for acquiring skills to be used in the occupation of their choosing.

Two-thirds of these young people said they would enroll for vocational courses if such courses were made available. This means that many young people not intending to go to school would be interested in taking specific training courses along some vocational line. The types of training which most interested them are shown in figure 3. Two out of five boys who said they might enroll for vocational courses if such courses were available, wanted training in some mechanical line—59 percent of those surveyed by field workers, and 14 percent of the boys in vocational classes. Of the latter, the great majority were most interested in vocational agriculture.

The girls' major interest was in commercial courses, both in-school and out-of-school girls desiring this type of training. Not many of the girls who were still in school wanted home economics courses, but to the girls who had left school, such training was considered as important as commercial and business courses. The girls were definitely interested in professional preparation. Not many wanted to be teachers, but one girl out of seven showed interest in nurse's training courses.

The Social Life of Rural Youth

The young people's leisure-time pursuits were distributed over a wide field, with moving pictures and the radio furnishing the most frequent diversions. Nine out of 10 boys and girls listened to the radio at least once a week, and 3 out of 7 attended more than one "movie" a week.

Some differences were found between forms of recreation enjoyed by those in school and those out of school. In general, the in-school youth patronized the more informal leisure activities such as reading, riding, engaging in hobbies, participating in sports, and dancing. Out-of-school youths depended more upon the commercialized forms of recreation: moving pictures, public dances, bowling, and roller-skating.

One in 10 of the youths did not belong to any organization. Most young people belonged to one or two organizations, and the girls had, on the average, a wider membership than the boys. Church, Sunday School, and young people's church groups were listed most frequently, and yet one out of four boys, and one out of seven girls reported having taken no part in church groups during the last year. All other organizations together were not attended by more than one-half the boys or two-fifths of the girls.

The out-of-school group was apparently not being reached either by religious or by secular organizations. This would seem to indicate that if social groups, in the churches or out of them, are to continue to attract young people, programs must be developed that will interest the older group of young folks.

The Organizational Needs of Rural Youth

Apparently these young people felt the lack of programs especially adapted to their needs. A fourth of them said there was no organization in their community that had a program for young people. Among the replies of those who thought otherwise, the 4-H Club, the Grange, and the churches were mentioned (in that order) most frequently.

A program which would attempt to meet more fully the needs of older rural youth was thus definitely indicated, but opinion was divided as to whether there should be a completely new organization. Just half of the group wanted such an organization, slightly more than a third did not feel the need of any, and the

others were undecided. The girls, particularly the out-of-school girls, felt the need of a new organization most strongly.

To the question as to what types of new programs they would like to participate in, the answers showed that purely "social" activities, including dancing, were not thought to be important. Only 7 percent of the responses were concerned with this type of social program. Economic interests, on the other hand, received by far the most attention, and after these in importance came programs concentrating on the improvement of personality. Evidently the young people wanted a type of social organization which would help them to overcome their problems—and their problems are principally economic.

Recommendations

The specific needs of these youths vary to some extent in the different towns, so that definite recommendations will depend on facilities already available in the local community. The young people themselves are in the best position to determine the application of programs designed to meet their needs. A program which would enlist their support in this way would go a long way toward filling one of their most basic needs—the opportunity to gain recognition and a sense of their own importance.

More vocational training is wanted by these young people. Repercussions of the National Defense Program have shown vividly that this is more than a personal need. An expanded vocational training program for rural youth is imperative.

Present social organizations are not satisfying the needs of the older rural youths. The 4-H Service Club or the Grange might be expanded to meet these requirements. Any organization trying to meet the needs of this group should offer a program designed to help young people in the solution of their economic and vocational problems. In the past too much attention has been given to recreation.

Adequate placement service is lacking for rural young people. The study has shown plainly the need for more adequate means of finding employment opportunities and allocating individuals to them. It might be desirable for high-school teachers to discuss public and private employment services in their classes.

It must be recognized that the needs of the young people are interrelated, so that one need can not be touched without influencing others. For example, the desire for more and better job opportunities on the part of these youths will almost certainly be affected if the desire for more vocational training is satisfied. Moreover, these young people have shown that they want their social organizations to fit in more closely with their struggle to achieve recognition in society.

This brings out at least one further consideration. In getting jobs, the young people showed that they have had to be largely self-reliant. Why not let them pool their self-reliance? A young people's community placement bureau, even though difficult to set up, would have the advantage of striking at several basic problems. It would provide the needed placement service, and would also enable the youths to demonstrate their own importance. In finding a place for boys and girls in our society, methods should be used which will afford them the best opportunities to work out their own destinities.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 387 December, 1941

Interrelationship of Land Uses in Rural Massachusetts

By David Rozman

The extent and significance of the various land uses and their relationship to each other are analyzed with a view to providing a basis for a balanced system of land utilization.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

INTERRELATIONSHIP OF LAND USES IN RURAL MASSACHUSETTS

By David Rozman,[1] Research Professor in Economics

CONTENTS

INTRODUCTION

Until very recently, studies in land utilization with their conclusions and recommendations were often of only remote or academic significance as far as bringing about any changes was concerned. The most effective legislative measures were undertaken in the field of conservation where, through public purchase or governmental regulation, it was possible to provide for better care of certain rural land areas. As for the bulk of agricultural land resources, the matter was left primarily to various educational measures where action was very slow and in most cases rather uncertain.

This condition has been radically changed with legislative recognition of various action agencies dealing with the most important phases of agricultural activities in rural areas. The range of situations affected by the newly created or existing agencies, considerably reinforced, extends from the conservation and improvement of soil to the whole range of human relationships involving ownership, tenancy, land settlement, and other similar factors affecting the life of individuals and the character of the community. Moreover, with the organization of agricultural land-use planning committees on a town, county and state basis, the whole matter of land-use relationships has been put on a realistic basis with the possibility of effecting needed readjustments in cooperation with governmental action agencies. Under these conditions a greater opportunity is offered to the research worker to make immediate and direct application of the results of his study.

In the light of existing opportunities in the field of land utilization, it seems that two lines of research are of special significance. One is concerned with the clear presentation of the important factors entering into the picture of land utilization,

[1]The author wishes to acknowledge the contribution made by Ruth E. Sherburne and Gilbert Simpson of the Massachusetts State College in the work of classifying land areas as presented in this study.

dealing largely with topography, climate, the classification and preponderance of different types of soil, the character of land use, and the type of settlement in rural areas. The other concerns the fundamental relationships between agricultural and other uses of land, which are of special importance in the rural areas of an industrialized state like Massachusetts.

The physical conditions of land resources, with diversity of soils, topography, and climate, and the proximity to densely populated areas have combined to form a complicated pattern of land utilization in rural areas of Massachusetts. Agricultural land uses, moreover, are determined in many cases by the type and character of other kinds of land utilization which have come into prominence over a period of time. To determine the present condition of agricultural land use in the State it is important, therefore, not only to indicate various factors directly related to farming, but to analyze the elements of interdependence existing among a number of land uses.

SOURCES OF INFORMATION

In preparation of this bulletin, field studies were made in conjunction with an analysis of existing basic data pertaining to land utilization. Beginning with the Census of 1925 statistics on important agricultural matters became available by minor civil divisions. This gave an opportunity to gain a clearer insight into the agricultural situation by the analysis of individual rural communities. For an exhaustive study of land utilization in a locality it is, however, essential to have more than these general data. The basic problem is to know how different land uses are distributed in the community and where they are located. This involves detailed mapping of agricultural and other important land uses in rural areas. Such mapping was accomplished through the organization of and participation in a land-use survey sponsored by the State Planning Board and carried out by WPA workers throughout the entire area of the Commonwealth.[2] (Boston area and the Islands excluded.) The most important contribution of this survey lies in the fact that for individual communities and the State as a whole the use of land areas, mapped out on the scale of two inches to the mile, became definite as to the location of crop land, plowable and unimproved pasture, woodland, and settled and water areas. On a separate map of the same scale is indicated the location of farms as well as of other buildings in rural areas, including schools, churches, hospitals, stores, and other public and private structures.

Another important source of information was the soil survey made by the United States Soil Service over a period of years. In view of the diversity of soil types with their exceedingly scattered distribution in various areas it has been difficult to form a clear picture of their relative significance as presented by the extensive classification of the United States Soil Survey. In the present study all the soil types were divided into seven major groups largely on the basis of their texture and topography. By way of further simplification these groups were subdivided into areas of good, medium, or poor suitability for agricultural purposes. (Table 1) While for the purposes of agronomy and farm management such simplification may not be recognized as of sufficient accuracy or detail, from the standpoint of determining broad land-use relationships it appears to be of definite value and of sufficient scientific accuracy. On this basis the major types of land were mapped out for each town in the State.

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[2]By sponsoring and carrying out this survey, the Massachusetts State Planning Board, under the chairmanship of Miss Elisabeth M. Herlihy, provided a real working basis for effective planning in rural areas of the State.

TABLE 1. – PERCENTAGE OF LAND IN THREE MAJOR GROUPS CLASSIFIED ON THE BASIS OF SOIL AND TOPOGRAPHY, BY COUNTIES

County	Suitability for Agriculture		
	Good	Medium	Poor
Barnstable	1.8	29.2	62.8
Berkshire	23.0	27.0	46.0
Bristol	34.0	12.0	44.0
Essex	26.7	22.4	37.1
Franklin	21.3	33.7	40.8
Hampden	24.2	24.2	42.2
Hampshire	27.6	23.1	43.8
Middlesex	21.6	33.3	28.7
Norfolk	29.1	14.0	42.5
Plymouth	20.8	11.0	57.7
Worcester	30.0	32.7	28.7

As a part of the classification essential for the background of land utilization analysis, two other maps were worked out: one indicating topography by means of contours adapted from the United States Topographical Survey, and the other showing in detail the location of roads and waterways in the individual towns. With all this detailed information available in a series of five maps for each community, and with all factors presented on the same scale, it has become possible to study the fundamental land-use relationships in a most comprehensive and definite form. These basic data have been further tested and analyzed in local land-use planning committees and field studies in individual communities.

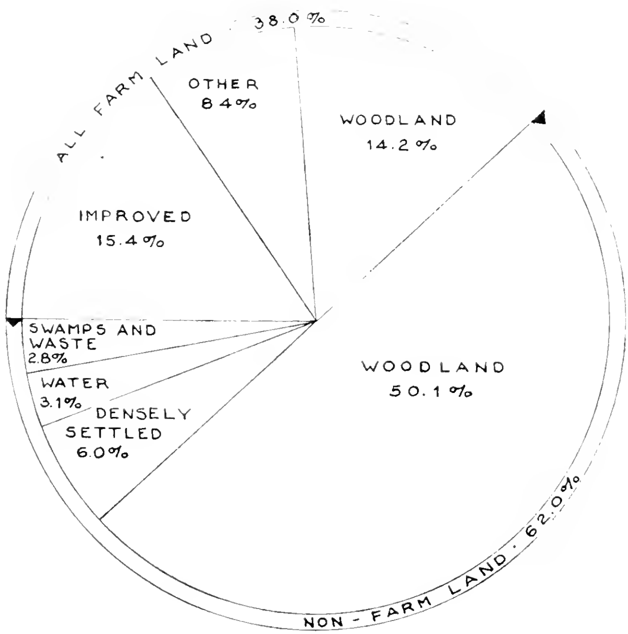


Chart I. Land Utilization in Massachusetts
Based on Land Use Survey of 1936-38 and U. S. Census, 1940

TREND OF LAND UTILIZATION IN MASSACHUSETTS

The first factor that comes to the attention in a land utilization study in Massachusetts is the general trend in the amount of land used for agricultural purposes.

Land in Farms

In 1880, when agricultural land utilization was still high, about two-thirds of the total area of the State was included in farming, as compared with the present farming area of only 38 percent. This means that more than 1,400,000 acres of land, representing almost 26 percent of the total area of the Commonwealth, went out of agricultural use. In 1880 the highest proportion of land included in farms was found in Hampshire, Franklin, and Berkshire counties, each having about 80 percent of its total area in farming. (Table 2) At the present time Hampshire and Franklin counties maintain their lead, but the proportion of land in this classification amounts to about 50 percent only. The smallest proportion of land in farming in 1880 was in Barnstable County, which retains the same position at the present time, but the percentage now is only 13.9 as compared with 29.5 in 1880.

Improved Land

The changes in total land area included in farms present only a partial picture of the situation. Of much more significance is the trend in improved land which is actually being utilized for agricultural purposes. In this direction the decline has been much more pronounced. From 2,128,311 acres or 41.4 per cent of the total area of the Commonwealth, it has declined to 787,815 acres or 15.5 percent.

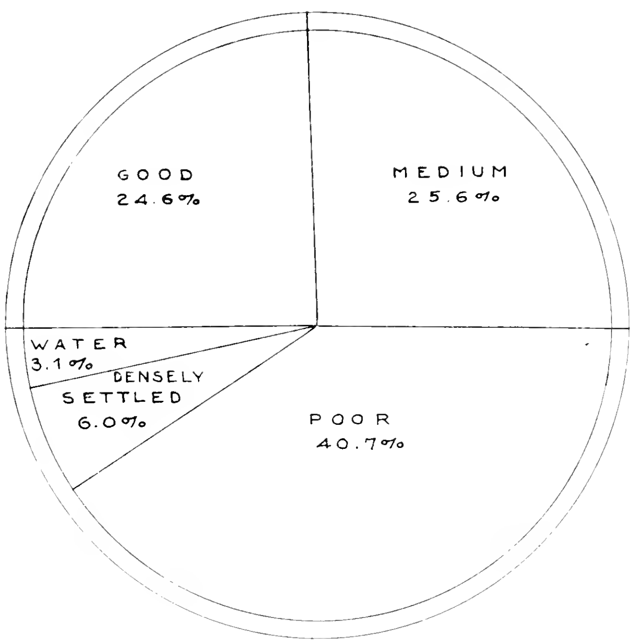


Chart II. Land Classification in Relation to Suitability for Agricultural Utilization

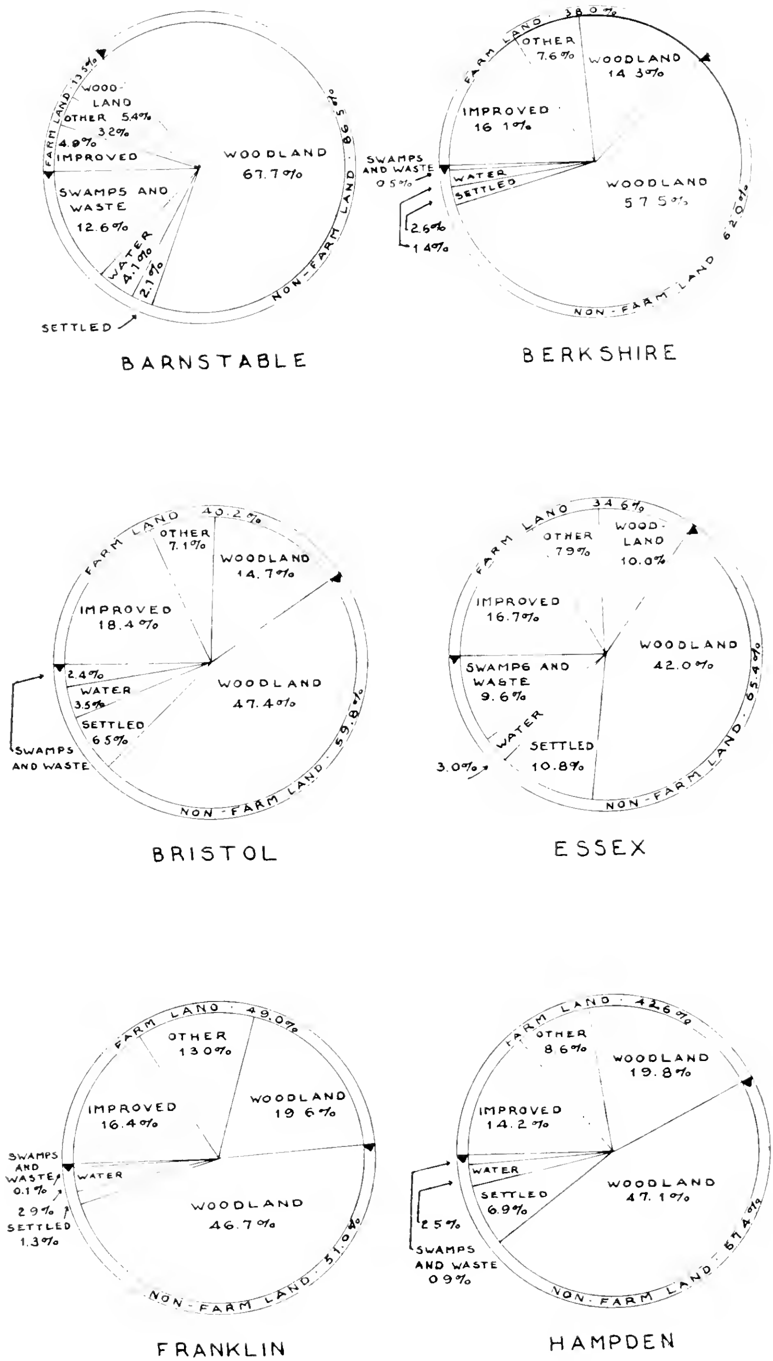
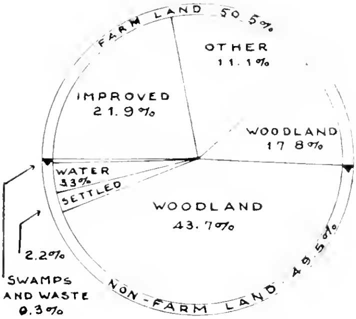
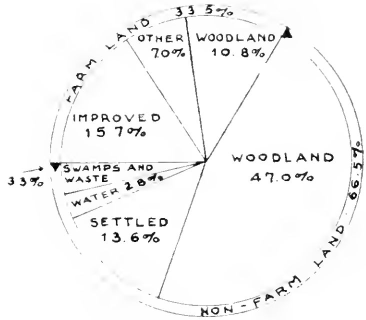


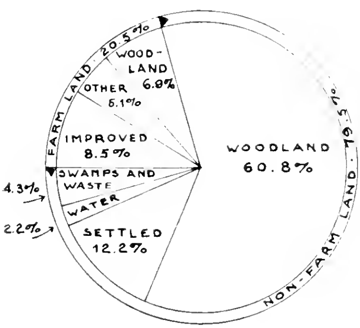
Chart III. Land Utilization in Massachusetts by Counties Based on Land Use Survey of 1936-38 and U. S. Census, 1940



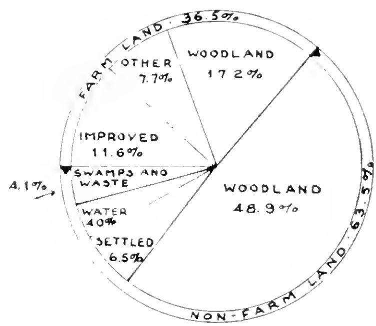
HAMPSHIRE



MIDDLESEX



NORFOLK



PLYMOUTH

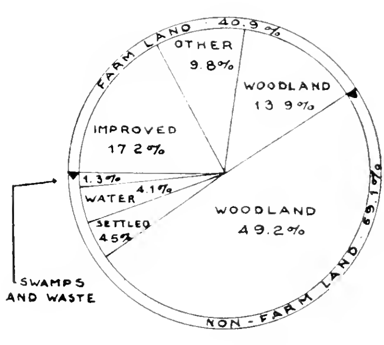


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Chart III. Land Utilization in Massachusetts by Counties
Based on Land Use Survey of 1936-38 and U. S. Census, 1940

Table 2. — Percentage of Total Area Suitable for Agriculture, in Farms, and in Improved Land

County	Percent of Land Suitable for Agriculture	Percent of Total Area in Farms		Percent of Total Area Improved	
		1880	1940	1880	1940
Barnstable	31.0	29.5	13.9	12.7	5.0
Berkshire	50.0	79.2	38.2	51.9	16.2
Bristol	46.0	50.6	41.5	26.4	19.0
Essex	49.1	56.9	35.6	39.9	17.2
Franklin	55.0	79.2	49.2	52.0	16.5
Hampden	48.4	74.1	43.7	45.4	14.6
Hampshire	50.7	80.5	51.4	54.8	22.3
Middlesex	54.9	72.3	34.2	49.1	16.1
Norfolk	43.1	45.6	20.8	27.0	8.6
Plymouth	31.8	44.1	38.0	19.4	12.0
Worcester	62.7	70.9	42.1	47.1	17.7

The greatest decline in the proportion of improved land occurred in Berkshire County, the percentages for 1880 and 1940 being 51.9 percent and 16.2 percent respectively. At present the highest percentage of improved land, 22.3, is found in Hampshire County; the lowest, 5.0, in Barnstable County.

Land Suitability

The decline in the amount of total and improved land in farming raised the question whether the land withdrawn from agriculture was of a type that was not suitable for cultivation, because of the nature of the soil or topography. By analyzing the types of soil and the character of the topography from the general data presented in the United States Soil and Topographical Surveys, it was possible to work out a general classification of suitability of land for agricultural purposes for every community of the State and map these areas in considerable detail. In this way the percentages of land areas suitable for agriculture were obtained for each county. By examining Table 2 it will be observed that these percentages are in most cases in close correspondence with the amount of land actually used for agricultural purposes in 1880. This confirmation may serve as substantial evidence that the method of land classification employed is fairly accurate and may be used as a starting point for the analysis with a fair degree of reliability.

Berkshire, Franklin, Hampden, Hampshire, and Middlesex counties had reached the point of utilizing practically all the land suitable for agricultural development. As a matter of fact, in Berkshire and Hampshire counties the percentage of improved land was slightly higher than that indicated as suitable for agriculture. This may be partly accounted for by the fact that some of the good land areas have been utilized for residential or industrial purposes since that time. In contrast with other counties, a rather low degree of land utilization for agricultural purposes existed in 1880 in Norfolk, Bristol, Plymouth, and Barnstable counties. Evidently residential and recreational influences due to their location and proximity to the Boston settled areas were already exerting their power. It must be stated also that land classification in these counties does not come up to the same level of reliability as in the other counties. These were the first areas where the United States Soil Survey was made in Massachusetts and the types of soils were not always correctly designated.

Considering the State as a whole, about 50 percent of the total land area, according to the adopted classification, is designated as suitable for agriculture. The actual use of land for this purpose does not amount at the present time to more than 15 percent. For the purposes of detailed study in individual communities the major types of land have been mapped by towns. The percentages of land suitability by individual towns are presented in Table 3.

TABLE 3. — PERCENTAGE OF LAND SUITABILITY BY TOWNS

Town or City	Suitability for Agriculture			Settled Areas	Water
	Good	Medium	Poor		
Barnstable County					
Barnstable	1.4	40.2	52.0	2.3	4.1
Bourne	0.0	14.8	80.9	3.0	1.3
Brewster	0.0	31.4	57.4	.8	10.4
Chatham	1.4	2.0	90.7	3.2	2.7
Dennis	6.2	48.1	37.7	2.3	5.7
Eastham	1.5	44.5	51.3	.3	2.4
Falmouth	0.0	49.5	46.1	1.8	2.6
Harwich	7.9	2.6	77.2	5.7	6.6
Mashpee	1.3	18.5	71.6	.5	8.1
Orleans	5.1	10.1	81.9	1.2	1.7
Provincetown	1.4	0.0	90.8	3.2	4.6
Sandwich	2.8	43.3	49.8	1.8	2.3
Truro	0.0	1.4	93.6	.8	4.2
Wellfleet	0.0	4.4	92.8	1.1	1.7
Yarmouth	2.0	53.6	35.8	3.1	5.5
The County	1.8	29.2	62.8	2.1	4.1
Berkshire County					
Adams	11.8	27.7	57.5	2.9	.1
Alford	33.3	30.9	35.8	0.0	0.0
Becket	14.2	15.7	67.1	.7	2.3
Cheshire	21.4	32.3	43.4	1.0	1.9
Clarksburg	11.5	28.7	56.2	3.0	.6
Dalton	17.6	28.7	50.3	3.2	.2
Egremont	43.0	22.4	32.1	1.7	.8
Florida	7.4	32.1	59.7	.1	.7
Great Barrington	19.0	27.5	46.5	6.1	.9
Hancock	15.7	13.8	70.3	.1	.1
Hinsdale	21.9	40.8	33.4	1.6	2.3
Lanesborough	37.1	22.0	37.6	1.3	2.0
Lee	28.8	11.0	53.4	4.6	2.2
Lenox	42.0	22.6	31.1	3.8	.5
Monterey	28.1	26.8	41.9	.7	2.5
Mount Washington	0.0	17.8	81.7	0.0	.5
New Ashford	7.6	18.4	74.0	0.0	0.0
New Marlborough	27.6	36.7	35.1	.2	.4
North Adams	16.5	16.9	51.7	14.4	.5
Otis	7.8	37.9	48.5	.2	5.6
Peru	4.0	47.5	48.3	0.0	.2
Pittsfield	47.5	16.2	14.0	18.2	4.1
Richmond	50.0	25.8	22.5	1.1	.6
Sandisfield	11.8	30.3	56.2	.8	.9
Savoy	8.2	39.6	51.9	0.0	.3
Sheffield	48.1	23.8	24.2	2.1	1.8
Stockbridge	32.9	29.2	27.8	6.5	3.6
Berkshire County—Cont.					
Tyringham	8.7	29.5	58.4	2.3	1.1
Washington	14.2	23.8	60.5	0.0	1.5
West Stockbridge	33.7	16.5	44.3	4.0	1.5
Williamstown	39.2	22.8	36.2	1.5	.3
Windsor	14.7	44.8	40.1	0.0	.4
The County	23.0	27.0	46.0	2.6	1.4
Bristol County					
Acushnet	42.8	8.1	40.2	4.6	4.3
Attleborough	27.6	6.9	53.3	11.3	.9
Berkley	19.3	36.1	39.2	.3	5.1
Dartmouth	40.9	6.4	47.0	4.2	1.5
Dighton	6.0	39.9	49.9	1.8	2.4
Easton	47.6	2.4	46.5	2.1	1.4
Fairhaven	43.5	0.0	32.7	21.8	2.0
Fall River	27.2	0.0	35.0	24.2	13.6
Freetown	46.1	7.7	39.4	2.3	4.5
Mansfield	35.0	12.0	48.4	3.5	1.1
New Bedford	21.7	1.5	42.1	30.5	4.2
North Attleborough	43.7	5.9	43.7	4.6	2.1
Norton	38.3	8.0	46.5	2.1	5.1
Raynham	43.7	4.9	47.5	1.8	2.1
Rehoboth	8.0	27.8	63.3	.5	.4
Seekonk	31.6	5.6	58.3	4.2	.3
Somerset	24.4	28.4	23.1	7.8	16.3
Swansea	15.8	19.9	58.7	2.6	3.0
Taunton	26.9	27.3	31.5	11.6	2.7
Westport	62.2	2.3	30.7	.8	4.0
The County	34.0	12.0	44.0	6.5	3.5
Essex County					
Amesbury	38.6	35.0	8.6	9.4	8.4
Andover	27.2	39.7	22.7	7.6	2.8
Beverly	32.8	7.0	44.6	14.2	1.4
Boxford	25.8	53.6	16.2	2.0	2.4
Danvers	43.6	13.7	23.2	18.1	1.4
Essex	16.9	6.4	72.0	3.3	1.4
Georgetown	18.8	47.8	28.9	3.2	1.3
Gloucester	.5	.8	89.5	8.2	1.0
Groveland	35.1	28.2	28.2	3.5	5.0
Hamilton	34.6	24.2	35.9	3.1	2.2
Haverhill	58.1	11.2	8.1	15.0	7.6
Ipswich	17.6	26.5	49.3	6.2	.4
Lawrence	14.8	7.9	2.2	68.2	6.9
Lynn	3.0	1.2	38.2	51.0	6.6
Lynnfield	19.1	39.3	29.6	9.5	2.5

TABLE 3. — PERCENTAGE OF LAND SUITABILITY BY TOWNS—continued

Town or City	Suitability for Agriculture			Settled Areas	Water
	Good	Medium	Poor		
Essex County—Cont.					
Manchester	6.3	8.2	63.5	22.0	0.0
Marblehead	10.6	3.8	34.0	51.1	.5
Merrimac	68.5	13.2	8.8	5.5	4.0
Methuen	47.5	29.7	12.8	7.2	2.8
Middleton	15.2	38.8	37.5	7.2	1.3
Nahant	5.0	0.0	21.9	71.5	1.6
Newbury	12.0	5.8	79.3	1.4	1.5
Newburyport	5.2	31.7	38.8	17.5	6.8
North Andover	42.1	28.8	21.0	3.8	4.3
Peabody	28.2	26.8	34.3	8.6	2.1
Rockport	4.2	2.7	82.4	9.9	.8
Rowley	10.2	31.6	57.8	.3	.1
Salem	3.2	1.7	60.0	32.8	2.3
Salisbury	6.3	37.8	47.4	6.1	2.4
Saugus	12.3	1.9	44.9	32.2	8.7
Swampscott	5.5	.3	17.5	76.1	.6
Topsfield	37.2	31.8	28.7	1.9	.4
Wenham	39.9	13.5	37.0	4.1	5.5
West Newbury	61.2	9.7	22.1	1.8	5.2
The County	26.7	22.4	37.1	10.8	3.0
Franklin County					
Ashfield	35.9	28.2	35.4	.4	.1
Bernardston	21.5	59.3	18.2	.8	.2
Buckland	10.7	43.6	44.3	.4	1.0
Charlemont	20.7	29.4	47.7	.4	1.8
Colrain	15.3	47.0	37.0	.2	.5
Conway	15.9	43.9	39.4	.6	.2
Deerfield	47.7	22.9	23.4	3.0	3.0
Erving	8.2	13.5	76.2	.7	1.4
Gill	50.4	34.5	8.9	.2	6.0
Greenfield	58.9	15.5	11.8	12.1	1.7
Hawley	24.4	16.6	58.7	.2	.1
Heath	44.4	29.5	25.9	.1	.1
Leverett	11.2	48.5	39.9	.3	.1
Leyden	34.4	36.7	27.8	.4	.7
Monroe	10.2	38.3	50.8	.3	.4
Montague	17.5	36.2	38.6	4.5	3.2
New Salem	7.8	11.2	60.3	.1	20.6
Northfield	15.5	16.7	63.3	1.5	3.0
Orange	4.9	38.9	49.2	4.8	2.2
Rowe	32.2	11.9	54.7	.1	1.1
Shelburne	20.8	36.4	40.9	.8	1.1
Shutesbury	3.5	66.1	29.1	.3	1.0
Sunderland	28.6	35.2	33.1	.3	2.8
Warwick	5.9	42.2	50.3	.4	1.2
Wendell	5.6	53.4	40.1	.1	.8
Whately	46.5	36.5	15.2	.1	1.7
The County	21.3	33.7	40.8	1.3	2.9
Hampden County					
Agawam	59.3	17.1	13.0	6.6	4.1
Blandford	19.4	24.0	52.6	.5	3.5
Brimfield	18.0	41.5	39.7	.4	.4
Chester	16.2	19.7	62.6	.6	.9
Chicopee	16.7	44.7	8.7	25.2	4.7
East Longmeadow	65.7	4.5	18.8	10.9	.1
Hampden County—Cont.					
Granville	13.9	17.3	66.6	.5	1.7
Hampden	24.6	17.5	57.1	.6	.2
Holland	16.4	48.3	30.1	.7	4.5
Holyoke	16.1	6.8	51.5	18.2	7.4
Longmeadow	21.5	36.1	19.9	16.3	6.2
Ludlow	28.9	14.9	47.6	3.9	4.7
Monson	16.5	23.5	57.6	2.1	.3
Montgomery	8.1	20.3	70.1	.1	1.4
Palmer	17.1	23.3	52.8	4.6	2.2
Russell	6.2	18.9	71.3	1.0	2.6
Southwick	48.8	12.9	35.2	1.1	2.0
Springfield	10.5	38.2	6.8	40.3	4.2
Tolland	9.0	20.1	68.1	.1	2.7
Wales	14.9	48.4	33.2	2.2	1.3
Westfield	48.0	25.0	13.1	12.5	1.4
West Springfield	39.2	18.0	17.8	20.5	4.5
Wilbraham	34.2	28.5	34.0	2.0	1.3
The County	24.2	24.2	42.2	6.9	2.5
Hampshire County					
Amherst	38.7	29.8	24.4	6.8	.3
Belchertown	32.1	20.8	42.6	.9	3.6
Chesterfield	21.7	27.1	50.1	.1	1.0
Cummington	27.2	31.0	41.1	0.0	.7
Easthampton	45.5	21.2	20.5	10.1	2.7
Goshen	20.3	43.5	33.4	.5	2.3
Granby	23.5	21.9	53.6	.2	.8
Hadley	57.7	9.2	24.7	1.8	6.6
Hatfield	39.4	21.1	33.9	.9	4.7
Huntington	17.3	19.7	60.0	.9	2.1
Middlefield	26.6	0.0	72.8	.1	.5
Northampton	32.5	30.4	26.1	8.2	2.8
Pelham	16.2	0.0	76.3	0.0	7.5
Plainfield	31.1	21.9	46.5	0.0	.5
South Hadley	28.1	27.6	36.5	4.2	3.6
Southampton	26.0	27.7	44.1	.8	1.4
Ware	13.5	33.8	28.9	6.2	17.6
Westhampton	12.3	15.4	70.9	.3	1.1
Williamsburg	15.8	42.3	39.5	2.2	.2
Worthington	37.6	17.7	44.4	0.0	.3
The County	27.6	23.1	43.8	2.2	3.3
Middlesex County					
Acton	19.8	49.0	24.8	5.1	1.3
Arlington	5.1	18.0	7.7	62.0	7.2
Ashby	24.9	26.8	46.2	.9	1.2
Ashland	14.0	42.7	38.1	1.0	4.2
Ayer	8.0	42.9	37.0	6.5	5.6
Bedford	36.6	18.7	39.7	4.1	.9
Belmont	8.2	14.4	7.9	68.0	1.5
Billerica	28.2	40.6	21.5	7.8	1.9
Boxborough	27.9	39.7	32.3	0.0	.1
Burlington	11.3	47.2	35.5	5.7	.3
Cambridge	7.2	0.0	9.5	70.9	12.4
Carlisle	11.3	49.5	37.8	1.0	.4

Table 3. — Percentage of Land Suitability by Towns—continued

Town or City	Suitability for Agriculture: Good	Medium	Poor	Settled Areas	Water
Middlesex County—Cont.					
Chelmsford	14.8	46.2	26.8	10.4	1.8
Concord	25.1	38.3	27.9	5.6	3.1
Dracut	27.9	36.3	23.5	10.2	2.1
Dunstable	14.3	56.9	27.8	.1	.9
Everett	6.2	0.0	4.1	79.4	10.3
Framingham	32.4	22.0	18.2	21.0	6.4
Groton	38.0	29.0	28.9	2.1	2.0
Holliston	32.2	33.1	29.4	4.2	1.1
Hopkinton	7.9	36.7	45.9	4.1	5.4
Hudson	11.2	65.5	13.8	8.2	1.3
Lexington	9.5	36.8	40.8	12.0	.9
Lincoln	18.1	39.9	38.3	1.3	2.4
Littleton	28.2	43.7	19.9	3.1	5.1
Lowell	5.2	4.3	4.6	79.7	6.2
Malden	10.0	0.0	15.1	73.9	1.0
Marlborough	32.8	32.7	22.0	7.8	4.7
Maynard	37.0	28.0	14.0	19.0	2.0
Medford	5.5	4.8	35.0	48.3	6.4
Melrose	7.8	2.8	14.6	73.3	1.5
Natick	29.4	26.3	18.4	19.0	6.9
Newton	12.1	4.2	10.3	71.0	2.4
North Reading	9.0	44.8	41.0	3.2	2.0
Pepperell	58.1	28.8	10.6	1.7	.8
Reading	16.2	22.8	36.8	24.1	.1
Sherborn	18.0	39.2	40.5	.9	1.4
Shirley	42.8	45.8	8.0	2.0	1.4
Somerville	8.0	0.0	.9	86.5	4.6
Stoneham	10.1	13.5	49.7	17.2	9.5
Stow	24.0	36.0	36.0	2.5	1.5
Sudbury	23.8	37.0	32.5	6.2	.5
Tewksbury	16.3	40.7	29.8	12.2	1.0
Townsend	21.0	42.4	32.5	3.6	.5
Tyngsborough	18.0	43.5	29.8	3.1	5.6
Wakefield	8.4	7.0	45.6	32.2	6.8
Waltham	8.1	24.0	23.9	35.8	8.2
Watertown	17.8	.7	.8	78.0	2.7
Wayland	27.2	30.5	31.7	6.9	3.7
Westford	18.3	31.7	42.9	4.7	2.4
Weston	33.3	22.6	40.8	2.2	1.1
Wilmington	9.8	53.0	26.5	10.5	.2
Winchester	9.0	20.5	36.5	28.0	6.0
Woburn	18.5	22.6	31.0	26.0	1.9
The County	21.6	33.3	28.7	13.6	2.8
Norfolk County					
Avon	9.4	28.2	54.0	5.2	3.2
Bellingham	43.6	16.1	36.4	2.2	1.7
Braintree	21.4	11.9	49.7	12.1	4.9
Brookline	11.0	3.8	23.5	58.8	2.9
Canton	22.1	20.4	52.2	3.4	1.9
Cohasset	12.0	.2	70.7	15.1	2.0
Dedham	16.6	6.0	48 8	26.0	2.6
Dover	32.9	13.7	49.3	3.1	1.0
Foxborough	46.3	13.5	31.7	3.6	4.9
Franklin	45.3	15.1	30.1	8.7	.8
Holbrook	18.8	21.8	52.1	7.1	.2
Medfield	27.9	17.9	50.6	3.0	.6
Medway	21.5	31.5	40.5	6.0	.5
Norfolk County—Cont.					
Millis	54.8	6.4	35.1	2.9	.8
Milton	37.7	4.4	53.2	4.0	.7
Needham	14.6	9.9	44.9	28.6	2.0
Norfolk	40.3	18.1	36.9	3.1	1.6
Norwood	25.9	10.6	39.3	23.1	1.1
Plainville	43.9	14.1	33.8	3.8	4.4
Quincy	5.5	3.8	30.7	59.2	.8
Randolph	7.4	26.1	53.0	11.1	2.4
Sharon	35.9	16.4	39.1	5.6	3.0
Stoughton	27.9	20.1	39.1	12.0	.9
Walpole	32.9	6.4	48.6	9.6	2.5
Wellesley	35.2	6.9	32.0	21.5	4.4
Westwood	32.3	9.4	48.4	9.1	.8
Weymouth	11.8	12.2	39.8	30.5	5.7
Wrentham	22.9	24.3	48.3	1.5	2.9
The County	29.1	14.0	42.5	12.2	2.2
Plymouth County					
Abington	37.5	0.0	51.0	9.8	1.7
Bridgewater	36.0	1.6	54.3	5.0	3.0
Brockton	25.4	.2	42.9	31.0	.5
Carver	5.1	24.4	66.7	.8	3.0
Duxbury	19.4	15.0	61.5	3.3	.8
East Bridgewater	28.8	1.8	56.9	10.1	2.4
Halifax	26.0	6.1	59.9	1.0	7.0
Hanover	35.3	4.2	52 2	7.2	1.1
Hanson	27.5	7.4	53.0	8.0	4.1
Hingham	14.7	15.1	59.8	9.9	.5
Hull	3.1	0.0	8.0	85.0	3.9
Kingston	14.3	11.2	66.7	5.6	2.2
Lakeville	15.5	10.7	52.7	2.8	18.3
Marion	14.8	0.0	79.8	5.2	.2
Marshfield	11.3	9.7	67.4	11.0	.6
Mattapoisett	7.4	1.0	88.0	3.5	.1
Middleborough	30.1	5.5	55.6	4.7	4.1
Norwell	31.8	5.2	59.2	2.1	1.7
Pembroke	32.2	5.7	50.0	4.7	7.4
Plymouth	3.1	30.9	56.7	3.8	5.5
Plympton	34.7	3.6	59.8	.1	1.8
Rochester	39.2	1.3	52.7	.5	6.3
Rockland	26.2	1.5	43.4	28.0	.9
Scituate	24.4	2.0	60.4	12.2	1.0
Wareham	19.3	17.1	54.6	5.4	3.6
West Bridgewater	33.9	.2	56.1	8.1	1.7
Whitman	23.7	0.0	40.6	31.5	4.2
The County	20.8	11.0	57.7	6.5	4.0
Worcester County					
Ashburnham	19.4	13.6	60.4	2.3	4.3
Athol	21.8	16.4	52.6	7.0	2.2
Auburn	37.3	23.7	27.5	7.0	4.5
Barre	26.7	36.4	33.9	1.9	1.1
Berlin	21.6	32.5	42.5	1.6	1.8
Blackstone	31.2	40.8	19.9	5.2	2.9
Bolton	29.8	43.7	24.9	.9	.7
Boylston	13.9	38.3	26.3	2.3	19.2

TABLE 3. — PERCENTAGE OF LAND SUITABILITY BY TOWNS—continued

Town or City	Suitability for Agriculture: Good	Medium	Poor	Settled Areas	Water
Worcester County—Cont.					
Brookfield	24.9	36.3	29.9	3.3	5.6
Charlton	54.9	29.2	12.6	.8	2.5
Clinton	11.3	26.3	13.1	23.6	25.7
Douglas	14.4	30.9	50.1	1.3	3.3
Dudley	46.1	23.2	21.6	5.0	4.1
East Brookfield	32.4	30.9	27.1	4.0	5.6
Fitchburg	27.3	18.4	29.5	22.9	1.9
Gardner	31.8	31.6	22.1	11.1	3.4
Grafton	37.8	35.5	21.2	3.0	2.5
Hardwick	17.2	26.8	51.2	.9	3.9
Harvard	24.0	55.9	15.2	2.6	2.3
Holden	26.7	42.6	25.1	3.7	1.9
Hopedale	37.1	27.9	18.8	12.9	3.3
Hubbardston	36.6	40.2	19.8	.1	3.3
Lancaster	39.7	42.9	10.2	6.2	1.0
Leicester	39.8	36.7	14.5	2.2	6.8
Leominster	32.8	34.9	18.8	11.1	2.4
Lunenburg	52.9	16.7	22.9	2.3	5.2
Mendon	23.1	46.2	28.0	1.5	1.2
Milford	21.8	34.5	32.5	10.8	.4
Millbury	31.7	43.4	13.2	8.0	3.7
Millville	16.9	39.9	34.2	7.2	1.8
New Braintree	37.2	40.3	21.3	.1	1.1
Northborough	22.1	51.4	24.0	1.6	.9
Northbridge	28.0	38.5	21.3	6.3	5.9
North Brookfield	45.3	30.0	17.7	3.5	3.5

Town or City	Suitability for Agriculture: Good	Medium	Poor	Settled Areas	Water
Worcester County—Cont.					
Oakham	37.8	46.3	14.3	.5	1.1
Oxford	42.4	27.9	24.5	2.7	2.5
Paxton	65.4	11.8	17.2	.8	4.8
Petersham	13.7	20.9	44.5	.3	20.6
Phillipston	26.6	4.8	66.1	.1	2.4
Princeton	24.5	44.6	29.8	.2	.9
Royalston	15.2	6.2	77.1	.4	1.1
Rutland	50.0	33.0	14.7	.8	1.5
Shrewsbury	22.3	44.1	19.2	8.5	5.9
Southborough	29.1	32.3	22.7	5.4	10.5
Southbridge	19.5	51.1	19.4	8.3	1.7
Spencer	44.3	37.1	13.6	2.4	2.6
Sterling	46.4	38.4	11.5	.7	3.0
Sturbridge	13.4	57.2	23.3	2.0	4.1
Sutton	32.7	29.2	32.9	1.1	4.1
Templeton	29.8	27.1	38.5	2.3	2.3
Upton	22.4	56.7	18.2	2.0	.7
Uxbridge	35.4	38.0	22.5	2.5	1.6
Warren	21.7	43.9	31.0	2.3	1.1
Webster	17.0	23.6	30.2	13.5	15.7
Westborough	27.2	35.5	30.4	4.5	2.4
West Boylston	27.2	43.2	20.0	2.7	6.9
West Brookfield	26.1	37.3	31.3	2.7	2.6
Westminster	35.2	34.8	25.3	.7	4.0
Winchendon	38.3	26.7	28.3	3.6	3.1
Worcester	25.3	15.6	7.0	48.6	3.5
The County	30.0	32.7	28.7	4.5	4.1

FACTORS AFFECTING AGRICULTURAL LAND UTILIZATION

The extent to which land classified as suitable for agriculture on the basis of soil and topography will be actually cultivated depends on a number of different factors. From the data already examined it appears that in 1880 the degree of land utilization was high in most of the counties, and in five important counties it almost reached the practical limit of physical possibility. It remains to be seen why there has been such a considerable falling off in the amount of cultivated land and what major developments are likely to take place in the future. To account completely for the decline in the total area in farming would require the consideration of a wide variety of subjects, including such important factors as technological improvements of transportation and food preservation, a radical change in the methods of farm operation and farm living, and a number of competitive factors in land utilization and marketing emanating from other sections of the country and even from some foreign markets. In dealing with land utilization matters in this discussion it is intended to confine the analysis to the consideration of important factors related to the land as they evolved in Massachusetts.

There are two important sets of conditions which effected a reduction in the amount of cultivated land in Massachusetts. One relates to physical influences and the other to economic and social factors arising from the use of land.

PHYSICAL FACTORS

Climate

From the physical point of view primary consideration should be given to climate and the length of the growing season. While very great extremes in temperature in Massachusetts seldom occur for more than a few successive days, there is a considerable variation from one locality to another. On the average there are from 40 to 50 inches of rainfall during the year. The length of growing season is subject to wide variations depending mostly on local conditions, such as elevation and air drainage, proximity to the shore, and the influence of winds. A very uneven topography makes it difficult to indicate the length of growing season for any large area.

A recent study in Essex County (Map 1) brings out vividly the fact that individual farms in the same locality have their own climatic problems which must be closely studied in order to obtain the best results from farming operations.

Even with all these irregularities and variations in climatic conditions, the farm operators of a few decades ago were able to adjust themselves to a comparatively high level of utilization of the land resources. Under present-day conditions, however, when competitive factors are more potent and readjustments in production more frequent, climate often becomes a limiting factor. The introduction of each new crop into a locality is followed by a period of uncertainty during which some producers find that climatic conditions on their farms are unfavorable and lead to considerable losses with continued production of the same crop. The most important factor, however, which has contributed to many failures and the abandonment of much land, is the attempt of many farmers, especially vegetable growers, to advance or retard the growing season to meet competition from other areas. Failure under these conditions leaves the impression that the soil or climate is not favorable, whereas the true cause is the artificial forcing of a type of cultivation which runs contrary to the prevailing physical background. Some areas in the eastern part of the State, therefore, were left out of vegetable production and by virtue of their location in high-cost sections were also barred from less intensive types of agricultural utilization.

Erosion and Deterioration of Soil

With the withdrawal of land from agriculture in Massachusetts going on at a rapid rate over a period of several decades, there has been a constant increase in the forested area. The decline in agricultural land use has been traditionally explained in terms of economic pressure or technological changes. As for soil erosion and exhaustion, the general notion was that they were only minor factors in the agriculture of the State, all the more since the major portion of the State area was under protective forest cover. The first soil erosion reconnaissance survey made in Massachusetts early in 1930 indicated that very little soil erosion of much consequence existed in Massachusetts. Another survey made in 1938 indicated that soil erosion was more widespread and more serious than had been previously recognized. A more detailed study made in 1939 and 1940[3] came to the conclusion that accelerated erosion is both more extensive and more severe than the previous survey indicated. It was pointed out, furthermore, that erosion formerly was more severe and that many areas now under protective cover of grass or trees had suffered severe losses in the past. By accepting this point of view it is possible to explain to a considerable extent the retirement of

[3]Beaumont, A. B., and Kucinski, K. Conservation of Massachusetts Soils. Mass. State Col., Ext. Bul. 193, 1941.

land from cultivation which has occurred in Massachusetts during the last several decades. One must, however, guard against accepting this factor as one of exclusive or major importance. Examination of individual areas on the basis of the soil survey and the land-use survey indicates that in many localities large sections of land were abandoned where erosion and deterioration of soil could not have been of as much importance as in some of the areas still retained in cultivation.

Map 1. Frost Dates and Length of Frost-Free Season in Essex County
Prepared by Essex County Agricultural School from information supplied by local farmers

Both erosion and general soil exhaustion have been responsible for the withdrawal of land from agricultural cultivation primarily when combined with certain economic and social influences. In some areas, like the Connecticut Valley and a few market garden sections, cultivation has continued in spite of a high degree of erosion and considerable exhaustion of the natural fertility of the soil. In these areas high expenditures for fertilizers and other protective measures have been justified by the level terrain and the possibilities of an intensive type of farming.

ECONOMIC AND SOCIAL FACTORS

Non-Resident Land Ownership

An important factor which has contributed directly to the withdrawal of land from agricultural cultivation is connected with the social process which has been going on in Massachusetts and in other parts of New England ever since the end of the Civil War. The children of many old New England farmers either emigrated to the West or settled in the cities. On the death of the parents the farm was often retained but without active cultivation. It requires only a short period of time under Massachusetts climatic conditions for land remaining unattended to grow into brush and woods. Left to itself, even the best quality of land is ordinarily lost to farming. This process has been further accelerated in some localities by the purchase of farms by city people for recreational or other non-agricultural purposes. Such farming land is allowed to grow into woods, which becomes the predominant cover. That all these conditions have had a great effect on the trend of land utilization in Massachusetts is attested by the great extent of non-resident ownership. In a study made in 1932 of 71 towns, representing a fair cross section of the State, it was found that a little more than one-third of the total area was owned by non-residents. Almost one-half of the land owned by these non-residents had no buildings at all. Very little of this land was being used for farming and practically the entire area is now under some kind of forest cover.

Disappearance of Local Industries

Traditionally, agriculture in Massachusetts has been associated in most towns with some type of local industry. With the gradual disappearance of these industries in many towns, a considerable setback has been given to farming. According to a recent study the number of industrial employees in towns of less than 10,000 population has declined since 1895 more than 75 percent.[4]

Local industries provided both the opportunity for employment for the surplus labor of the farms and a good market for the farm products purchased by the employees. In many cases, with the disappearance of local industries, a portion of the employees emigrated to urban centers, and the farmers, not finding a convenient outlet for their products, were compelled to curtail their operations. When new market outlets were not found in a reasonably short time, much of the land went out of cultivation. Evidences of that condition are found throughout the State, but especially in some sections of Worcester County.

In some towns, however, in the vicinity of industrial communities or urban centers, the disappearance of local industries has not necessarily involved the loss of subsidiary employment for the local population. Better means of transportation have made it possible for a good many people to be employed at some

[4]Rozman, David, and Sherburne, Ruth E. Historical Trend in Massachusetts Industries, 1837-1933. Mass. Agr. Expt. Sta. Bul. 340, 1938.

distance from their home communities. Moreover, the growth of residential, recreational, and other uses of land in rural areas has provided many opportunities for the local farming population to render various services, including work with their teams. With the increase in all kinds of construction work in both cities and rural areas, and the introduction of modern highways, there has been a constantly increasing demand for such materials as gravel and sand. This has resulted in more intensive utilization of gravel and sand pits throughout the State wherever favorable sites are available. This is one type of industrial activity based on local natural resources that has experienced an upward rather than a downward trend in the rural areas of the State.

Land Values

In some areas the most important factor contributing to the curtailment of the amount of land used for agricultural purposes is the demand for land for other uses, largely related to residential, industrial, and certain types of recreational activities. When land becomes important for these more intensive uses, people are generally willing to pay higher prices for land. High land values, however, in many areas of Massachusetts, are not necessarily associated with actual use of the land for these more intensive purposes. It is sufficient for people to recognize that certain areas have a potential importance for other uses which may come in the immediate future or over a period of time. There may also be mistaken judgment, and certain areas may never come into the expected use. Nevertheless, as long as people generally agree that a higher use is forthcoming, the land values may be out of all proportion to values justified by the present use. In communities where land areas are affected by present or potential considerations for more intensive use, farm land is ordinarily valued at a higher level than is justified by its agricultural importance.

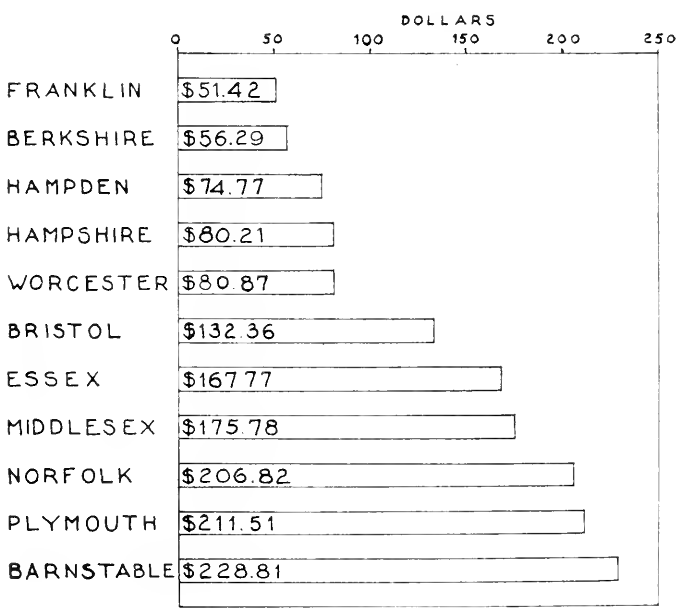

Chart IV. Value of Farm Land and Buildings, per Acre, by Counties Based on U. S. Census, 1940

The chart showing average farm land values by individual counties indicates a wide variation, with Franklin County at the lowest level of $20.78 and Barnstable County reaching $107.63 per acre. In considering these average farm land values it is important to keep in mind that they refer to all the land in farms irrespective of the cover and use. The land which is actually used for farming operations is, however, only a fraction of the total land area. (Table 4) For the State as a whole 40.5 percent of the total farm land is classified as improved. By individual counties it varies from 31.6 percent in Plymouth County to 48.2 percent in Essex. Thus it becomes clear that the average value for the land actually used in farming is at least twice as high as indicated by official figures. The fact that the average value per acre of farm land in Franklin County is the lowest in the State may be attributed, to a certain extent, to the small proportion of improved land. More important, however, is the general location of Franklin County and the low density of population that place it in a position where present or potential high land uses exert only a slight influence.

TABLE 4. — PERCENTAGE OF FARM LAND IMPROVED, BY COUNTIES

County	Percent of Farm Land Improved	
	1935	1940
Barnstable	32.5	36.3
Berkshire	31.0	42.3
Bristol	39.6	45.7
Essex	40.3	48.2
Franklin	25.5	33.5
Hampden	34.3	33.5
Hampshire	33.9	43.4
Middlesex	41.5	47.0
Norfolk	37.9	41.2
Plymouth	33.0	31.6
Worcester	35.8	42.0
The State	34.5	40.5

The average land value in Berkshire County is only slightly higher than in Franklin County, or $22.38 per acre. While Berkshire County is even farther removed from large centers of population and is, therefore, comparatively free from the influence of higher land uses in that direction, there is an important recreational factor related to exceedingly favorable local natural conditions. In addition, the proportion of land in farms classified as improved is somewhat higher than in Franklin County. In Hampshire, Hampden, and Worcester counties both the proportion of improved land in farms and the average value per acre of farm land are on about the same level, which, in the matter of land values, is almost 50 percent higher than in the two preceding counties. In general, farm land values per acre increase going from the western to the eastern part of the State. In all the counties lying east of Worcester the average value of farm land is over $50, with Plymouth and Barnstable exceeding $100 per acre. In all these counties land values reach a very high level by virtue both of greater pressure from higher land uses and of the fact that land in agriculture becomes more profitable because of proximity to densely settled consuming areas. Of these two influences the first is of far greater importance.

When the major factor in farm land values is connected with expectations of future land uses rather than with the current returns in agriculture, it becomes almost impossible for a producer dependent on the farm for his living to carry on stable farming. This is especially true in the case of the farmer who purchased his land at an inflated high level and who has to justify his investment on the basis of his returns in farming.

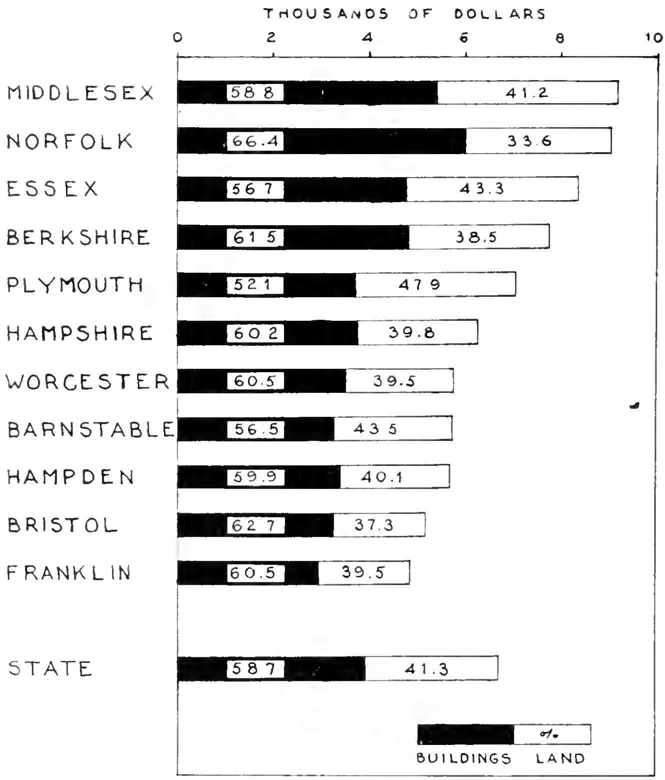

Chart V. Average Value of Farms and Percentage of Value in Land and Buildings, by Counties Based on U. S. Census, 1940

Value of Buildings

The cost of land is only one part of the fixed investment and overhead charges with which the farmer has to reckon. The other part is represented by the cost of buildings both for residence and for the needs of the farm. For the State as a whole, the average value of a farm on the basis of the 1940 Census was $6,647, of which 41.3 percent represents the value of land and 58.7 percent the value of buildings. In each county the value of buildings is higher than the value of land. In Norfolk County exactly two-thirds of the total value of farm real estate is represented by buildings. From the standpoint of profitability of farming operations, in some sections of Massachusetts and especially in the eastern counties, the large investment in buildings in addition to the high cost of land creates a real problem. It is true that the types of farming prevailing in Massachusetts as

well as in the entire northeast, especially dairy and poultry enterprises, involve considerable investment in farm facilities. It is also true that some of the farms are of a semi-residential type where people engaged in other lines of activity can afford to have more expensive buildings for residential or recreational purposes. Nevertheless, in cases where the farmer must justify his investment on the basis of farming operations, considerable caution is required. While it is generally recognized that high cost of land or high cost of farm buildings not fully utilized may lead to eventual failure, not enough attention has been given to the fact that in many cases failure results from investment in a type of farm house which is not justified by the particular farming business, especially for a farmer in the early part of his career.

TABLE 5. — DISTRIBUTION OF VALUE OF LAND AND BUILDINGS, BY COUNTIES 1940.

County	Average Value of Land and Buildings	Land		Buildings	
		Value	Percent	Value	Percent
		Per Acre			
Barnstable	$228.81	$107.63	47.0	$121.18	53.0
Berkshire	56.29	22.38	39.8	33.91	60.2
Bristol	132.36	50.70	38.3	81.66	61.7
Essex	167.77	76.01	45.3	91.76	54.7
Franklin	51.42	20.78	40.4	30.64	59.6
Hampden	74.77	30.71	41.1	44.06	58.9
Hampshire	80.21	33.28	41.5	46.93	58.5
Middlesex	175.78	76.15	43.2	99.63	56.8
Norfolk	206.82	80.38	38.9	126.44	61.1
Plymouth	211.51	104.74	49.5	106.77	50.5
Worcester	80.87	33.13	41.0	47.74	59.0
The State	109.40	47.08	43.0	62.32	57.0
		Per Average Farm			
Barnstable	$5,699	$2,477	43.5	$3,222	56.5
Berkshire	7,705	2,965	38.5	4,740	61.5
Bristol	5,105	1,903	37.3	3,202	62.7
Essex	8,349	3,619	43.3	4,730	56.7
Franklin	4,806	1,898	39.5	2,908	60.5
Hampden	5,645	2,266	40.1	3,379	59.9
Hampshire	6,206	2,467	39.8	3,739	60.2
Middlesex	9,166	3,774	41.2	5,392	58.8
Norfolk	9,011	3,025	33.6	5,986	66.4
Plymouth	7,045	3,376	47.9	3,669	52.1
Worcester	5,720	2,262	39.5	3,458	60.5
The State	6,647	2,748	41.3	3,899	58.7

TABLE 6. — AVERAGE SIZE OF FARMS, BY COUNTIES, 1940

County	Acres
Barnstable	24.9
Berkshire	136.9
Bristol	38.6
Essex	49.8
Franklin	93.5
Hampden	75.5
Hampshire	77.4
Middlesex	52.1
Norfolk	43.6
Plymouth	33.3
Worcester	70.7
The State	60.8

Farm Taxation

Closely connected with the level of farm land values and investment in the farm is the problem of taxation. The total amount paid by the farmer depends both on assessed valuation and on the rate of taxation. The comparison of rates from one town to another does not tell the whole story, inasmuch as there is a wide variation in the relationship between assessed valuation and true value. In Massachusetts there is a considerable difference from one town to another in this respect, as indicated by a farm tax study made at the Massachusetts Agricultural College.[5] In a group of ten towns the ratio between assessed value and owners' value varied from 41.9 percent to 62.4 percent.

TABLE 7. — AVERAGE TAX RATE IN TOWNS BELOW 10,000 POPULATION, BY COUNTIES, 1940

County	Tax Rate
Barnstable	$27.32
Berkshire	30.26
Bristol	32.76
Essex	34.41
Franklin	29.10
Hampden	31.62
Hampshire	30.45
Middlesex	32.05
Norfolk	31.98
Plymouth	30.80
Worcester	36.85
The State	32.16

The average tax rate for towns under 10,000 population, as imposed in 1940, amounted to $32.16. (Table 7) By counties, the highest average rate was in operation in Worcester County, with Essex County following; the respective figures being $36.85 and $34.41 per $1,000 of valuation. The lowest average rate is recorded in Barnstable County at $27.32.

[5] Yount, H. W. Farm Taxes and Assessments in Massachusetts. Mass. Agr. Expt. Sta. Bul. 235, 1927.

When tax rates are considered by towns the extent of variation becomes more pronounced. They range from $12.90 in the town of Boxborough in Middlesex County to $53 in the town of Warren in Worcester County. With such variations in assessments and tax rates, a more adequate measure of the weight of taxation on agriculture in individual communities will be obtained by taking the amounts paid either per acre of farm land or on the entire farm, as reported in the Agricultural Census.

Taxes on land and buildings per acre of farm land are indicated in Chart VI. The variation is from $1.02 per acre in Franklin County to $5.64 in Norfolk County. In general, individual counties exhibit the same relationships that have been found in the case of land values.

As shown in Chart VII, the same thing is true of taxes per farm. A notable exception is Barnstable County, where the tax per acre is close to the highest, but because of the small average size of farms the tax per farm is nearer to the lowest payment.

Both investment in farm real estate, as represented by land and buildings, and taxes paid represent fixed charges in the cost of farm operations and if too high have the effect of discouraging agricultural land utilization when all the charges are to be covered from farming operations. In attempting to make recommendations for agricultural land utilization in individual areas, therefore, the level of land values, the size of fixed investment, and taxation should be given primary consideration.

Residential Land Uses

With the increase of population in Massachusetts the amount of land used for residential purposes has been gaining constantly in importance. At the present time the total area of land used for residential, industrial, and commercial purposes in densely settled areas comprises about 6 percent of the entire area of the State. The proportion naturally varies from one county to another. The rural counties in the western part of the State have the lowest percentage of densely settled area, with 1.3 percent in Franklin and 2.6 percent in Berkshire County. The eastern counties have the highest percentages, Middlesex, Norfolk, and Essex counties having 13.6, 12.2 and 10.8 percent respectively. The only exception to this high percentage in the eastern section is Barnstable County, where the area so occupied amounts to only 2.1 percent of the county. Bristol and Plymouth counties each have 6.5 percent of land in settled areas; and Worcester County, in the central part of the State, has 4.5 percent, somewhat below the State average.

The amount of land in densely settled areas is not, however, under present conditions the only important indicator of the extent to which land is being used for residential purposes. In the last two or three decades, with the advent of the automobile, residential uses of land have extended into rural areas, with dwellings scattered far and wide. This is true especially in the eastern part of the State but also in the vicinity of urban centers in other sections. If the use of land for residential purposes in these widely scattered rural areas is taken into consideration, the total area of the State devoted to residential uses will be considerably higher than is indicated by the densely settled areas alone. A certain amount of land formerly in farming, especially in the eastern section of the State, has become a part of these expanding residential sites.

Average Tax per Acre of Farm Land (owner-operated farms), by Counties

Based on U. S. Census, 1940

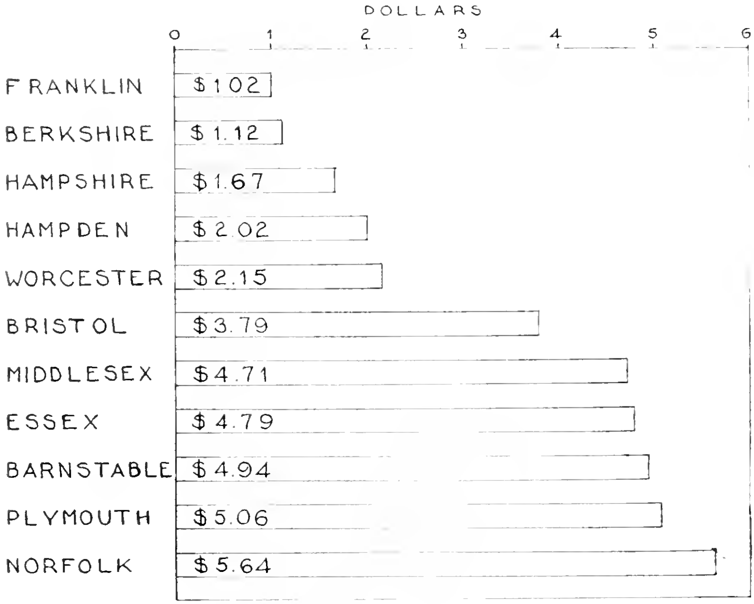

Chart VI. Average Tax on Land and Buildings

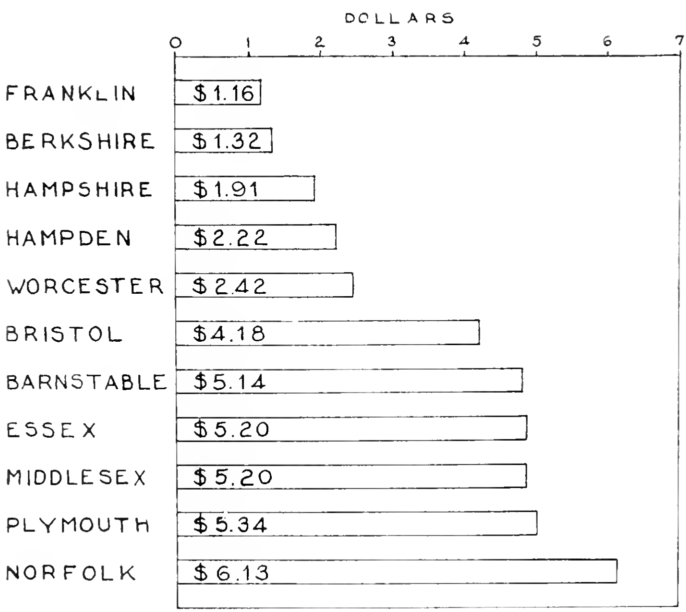

Chart VIII. Average Total Tax

Average Tax per Farm (owner-operated), by Counties

Based on U. S. Census, 1940

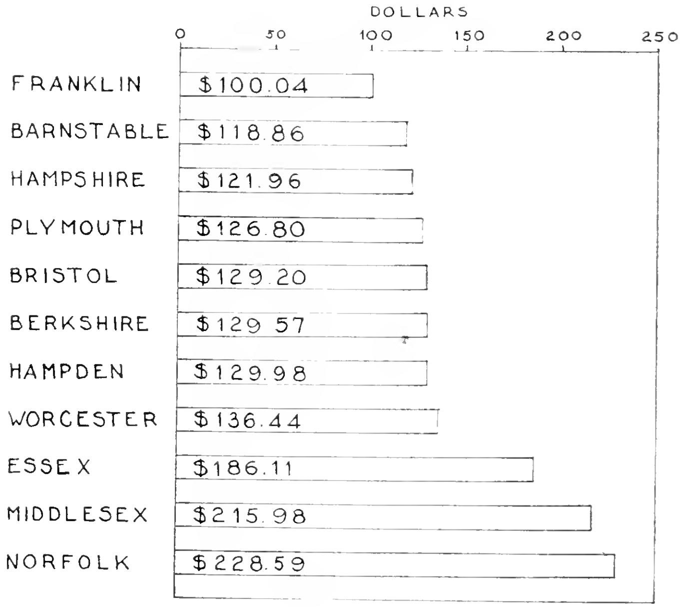

Chart VII. Average Tax on Land and Buildings

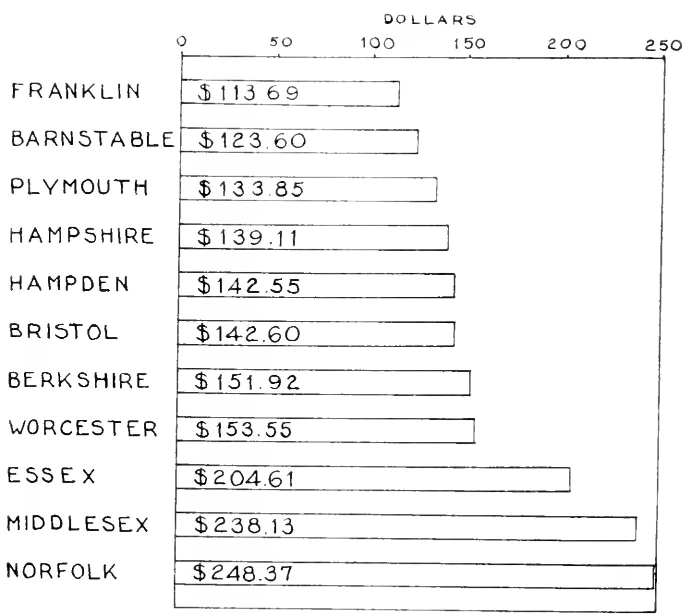

Chart IX. Average Total Tax

Part-Time Farming

Closely connected with residential land uses is the development of part-time farming. As a matter of fact, the desire to have residence in a rural environment has been one of the primary motives of a good many people in adopting part-time farming as a mode of living. Where farming is done on a very small scale, hardly sufficient to cover the essential requirements of the family in a few products, the residential element is undoubtedly dominant. Where part-time farming expands to the extent of not only fully covering the family requirements in a few essential products but even going into the production of a surplus for sale, the matter of additional income enters more fully into consideration. In most cases the decision to settle in part-time farming is based on a combination of several considerations: cheaper living, more acceptable housing conditions, especially for a large family, opportunities for better health because of country environment and more abundant fresh farm products, a certain amount of additional income combined with the security of owning a small farm—all these enter into the picture.[6]

Part-time farming has been on the increase in the State for the last two or three decades and is still advancing. One type of part-time farming, that carried on by retired people with an outside income, is slated now for a big increase. On the basis of recent social legislation a large number of people engaged in industries and trades will be retiring after a certain age with a definite income through the rest of their lives. Many of these, either because of a previous rural background or because of an urge for rural life, will be looking forward to settling on a piece of land in the country. Some of them are not waiting for the beginning of the retirement period and are already getting suitable holdings in readiness for that time. These tendencies have been definitely discovered in the studies of part-time farming carried on under this and other projects in Massachusetts.

To determine the extent of part-time farming is extremely difficult because of a variety of types existing in the State and the difficulty of formulating an adequate definition. The most recent complete figures available are for the Census of 1940. (Chart X) According to this information, 40 percent of the 31,897 farms included in the Census enumeration are operated on a part-time basis. Some part-time farmers are engaged in outside work on other farms, but the majority, comprising 84 percent of the total, are employed in industry and other occupations. The amount of time spent by part-time farmers outside of their own holdings varies widely. While only 17 percent of them spent less than 100 days per year in such work, 61 percent of them were engaged in outside activities to the extent of 200 days or more through the year.

The extent of part-time farming varies with the location and general conditions in a particular area. There is more part-time farming in towns with industrial enterprises and in rural areas in the vicinity of industrial centers. With the improvement of rural roads and better transportation facilities, commuting is possible for longer distances and part-time farming spreads over wider areas.

Much of the land previously in commercial farming is now being occupied by part-time farming. More of it will undoubtedly be taken, especially in the eastern part of the State. Considering the level of land values and the high taxes in the eastern counties, it is difficult to visualize much farming on a commercial scale carried on profitably in some of these areas. Inasmuch as the part-time farmer has an additional income and does not need as much land as an operator engaged in commercial farming, he can carry the load with much less difficulty. In addition, to the part-time farmer the expense of maintaining his holding is to a large extent a part of his housing costs.

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[6] Rozman, David. Part-Time Farming in Massachusetts. Mass. Agr. Expt. Sta. Bul. 266, 1930

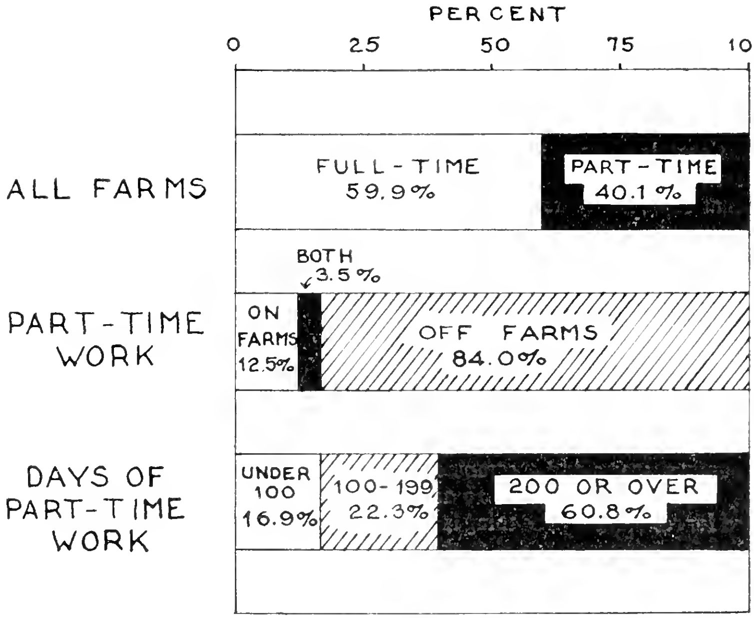


Chart X. Part-Time Farming in Massachusetts
Based on U. S. Census, 1940

Recreational Land Uses

The demand for recreational land uses has been increasing, mostly from two important causes: the congestion of people in densely settled areas, and the rising standard of living. Both of these causes have been operative in Massachusetts as well as in the rest of the country for a considerable time. In addition, large areas of land in Massachusetts are devoted to providing recreational facilities, especially in the form of summer homes for non-residents.

Opportunities for recreational land uses in Massachusetts are provided largely by wooded sections of hilly areas with their beautiful scenery, and by water areas both in the interior around numerous lakes, ponds, and rivers, and in the eastern part of the State along the seashore. The first type of recreation is mainly concentrated in the Berkshire area; while recreation connected with water attractions, even though scattered throughout the State, is of greatest importance on or near salt water.

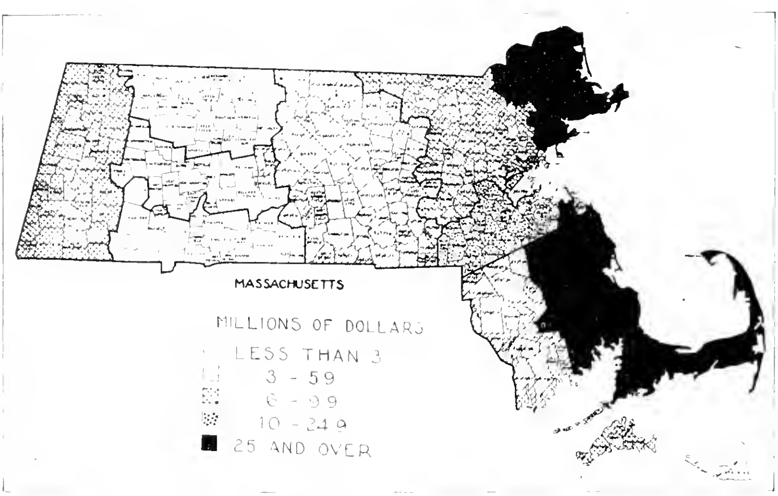
Recreational land uses are provided by both private and public sources. From the standpoint of private land utilization for recreational purposes, the greatest area is occupied by summer homes and private estates. Summer homes in the various sections of the State are coming into greater prominence and are likely to remain an important source of demand for a considerable time. For some communities the maintenance of summer homes has become the most important form of land utilization.

Public facilities for recreational needs involving the use of considerable areas of land are largely connected with parks, picnic areas, playgrounds, and beaches. Within recent years an important step has been taken by providing recreational facilities in the State forests. Since the State forests already occupy an area of almost 200,000 acres, even a limited utilization of some of the forests will mean considerable extension of recreational land uses.

Most of the recreational land is in the wooded hilly sections of the State or in areas with the least advantageous conditions for agriculture. The use of these areas for recreational purposes, therefore, does not offer real competition to agricultural land uses. Much of this land either never was in agricultural use or was abandoned prior to the advance of the interest in recreation. Some types of recreational land uses, however, expanded at the expense of agricultural land utilization. These are mostly intensive types located near urban centers or areas adjacent to bodies of water. The high desirability of these areas for recreational use brings the land values to a point where ordinary agriculture can not very effectively compete and is eventually driven out. This does not mean, however, that some of the farming areas adjacent to the intensive types of recreational land uses do not actually benefit from the existence of readily available and profitable markets during certain seasons of the year.

It is possible to conclude, therefore, that some areas previously in agriculture are now in recreational use. This, however, refers only to a very limited amount of land in special areas.

Because of the endless variety of recreational land uses, including both winter and summer sports and a combined use of land for recreational and other purposes, it is extremely difficult to determine exactly what proportion of the State is used for recreation. One thing is certain, that recreational land use is constantly growing in importance and that various communities have considerable amounts invested in recreational property. The survey made in 1930 by the Massachusetts Industrial Commission in cooperation with the New England Council disclosed these investments in Massachusetts communities. The amounts involved show to a certain extent the relative importance of recreational land uses in various parts of the State. The assessed valuation of recreational property amounted to $190,000,000 in the State as a whole. Essex County led with recreational property assessed at about $48,000,000; Plymouth County, with $44,000,000, was second; and Barnstable County, with $42,000,000, third. The variation by counties is indicated on Map 2.



Map 2. Assessed Value of Recreational Property, by Counties
Massachusetts Industrial Commission, 1940

Water Supply Areas

With the growth of urban areas and industrial centers in the State, it has become necessary to keep an increasing amount of land for water-supply systems. The areas involved are not only those actually under water but also the surrounding territory kept under control for the protection of the reservoirs. Some of the areas so kept were formerly in agricultural use and some would still be used if they were not incorporated into the water-supply systems. The largest area of land under a water system is controlled by the Boston Metropolitan Water System which extends far into the western part of the State. It has recently been augmented by the Quabbin Reservoir which caused the disappearance of four towns and reorganization in the areas of several others. The total area controlled by the Metropolitan Water System is 98,383 acres, the major portion of which is connected with the Quabbin Reservoir.

Airports and Flying Fields

Airports and flying fields have come into existence in some parts of the State and are being developed in others. This is another illustration of new uses for land which may take land already abandoned by agriculture as well as areas which are still valuable for farming.

Military Camps and Areas for Defense Activities

In several towns considerable land areas are being used for military camps. In connection with the present defense activities more land has been taken for various military needs, including some sections which are important from the standpoint of agricultural land utilization. This is not likely to continue beyond the present emergency, although some of the land taken out of farming now is likely to be permanently lost to agriculture.

Highways

The intensification of automotive traffic in the last two or three decades has been accompanied by an extensive program of highway construction. Some of the modern highways follow existing road facilities. Others have been constructed through new areas including some occupied by farming. This and the fact that the existence of new roads has made some of the adjacent land more valuable for purposes other than farming has resulted in a decrease in the total amount of land in agriculture. On the other hand, the construction and improvement of secondary roads in rural sections have been beneficial to some farming areas, making their cultivation more desirable and advantageous.

Woodland

One of the most important consequences of land utilization changes in Massachusetts during the last several decades has been a steady increase in land areas under wooded cover. As land areas under cultivation have gone out of use they have almost invariably developed a wooded cover—a natural thing under Massachusetts conditions. As determined from the analysis of the Land Use Survey, almost two-thirds of the total area of the State, is under wooded cover.[7] The variation by counties runs from the highest, 73.1 percent found in Barnstable

[7]This term includes all types of timber growth from brushland to good stands of merchantable timber.

County, to the lowest, 52.0 percent in Essex County and 57.8 percent in Middlesex. In the remaining counties the percentage of land under wooded cover is fairly close to the State average. (Table 8) Most of this woodland is located outside of farms, which contain only one-third of the total area under wooded cover. The greatest proportion of total woodland located on farms is in Hampden and Franklin counties where it amounts to about two-fifths of the total. Barnstable County, with the highest proportion of land in the whole State under wooded cover, contains the smallest proportion of it in farms.

Table 8. — Percentage of Total Area in Woodland, by Counties, 1941

County	Percent of Total Area	
	Farm Woodland	All Woodland
Barnstable	5.4	73.1
Berkshire	14.3	71.8
Bristol	14.7	62.1
Essex	10.0	52.0
Franklin	19.6	66.3
Hampden	19.8	66.9
Hampshire	17.5	61.2
Middlesex	10.8	57.8
Norfolk	6.9	67.7
Plymouth	17.2	66.1
Worcester	13.9	63.1
The State	14.2	64.3

With large areas of woodland present in the State, special emphasis must be placed on proper utilization of these areas, which, for the most part, remain neglected. In considering woodland, two different lines of approach should be made, depending on whether land is in farms or not. As far as farms are concerned, wooded areas are a part of the farm organization and the main effort should be directed towards proper treatment and better conservation methods.

The major section of woodland is, however, outside of farms, and of this about 10 percent is already in State and town forests. In this area a definite attempt is made to carry on forest management on a scientific and systematic basis. Although these publicly owned areas have many uses, including recreation and wildlife preservation, the primary purpose is to provide proper conservation methods in encouraging forest culture. There are very few other wooded areas in the State where the same objectives are maintained. The rest of the area is under rather scattered and confused ownership, with the major proportion held by nonresidents. These areas are being used for a variety of different purposes, some woodland in the eastern part of the State being held with the expectation of more intensive uses. This fact is reflected in land values, which are based in some sections not so much on the type of the timber stand as on the expectation of a more intensive type of land utilization.

Consideration of the tables indicating the proportion of farm land in woodland and the average values of farm land, shows that in some counties where more farm land is under wooded cover, land values are higher. This is especially true of Norfolk and Barnstable counties where more than half of the total farm land is in woodland.

Several attempts have been made in the past to provide foundations for the

development of wooded areas under a better system of management and conservation. One of the measures adopted by the Legislature gave the owner of woodland an opportunity to register his holding with the idea of deferring the time of tax payments until the timber is actually cut. This was expected to prevent indiscriminate cutting and to provide an incentive for better conservation practices. Experience with this law over a period of years, however, has not been very fortunate, inasmuch as very few woodland owners registered their land for forest development. A new law was passed this year which automatically provides for deferred payment of taxes on the timber on all woodland which is assessed for less than $25 per acre. It is possible that this will prove a turning point in the progress of land utilization under wooded cover in extensive sections of the State.

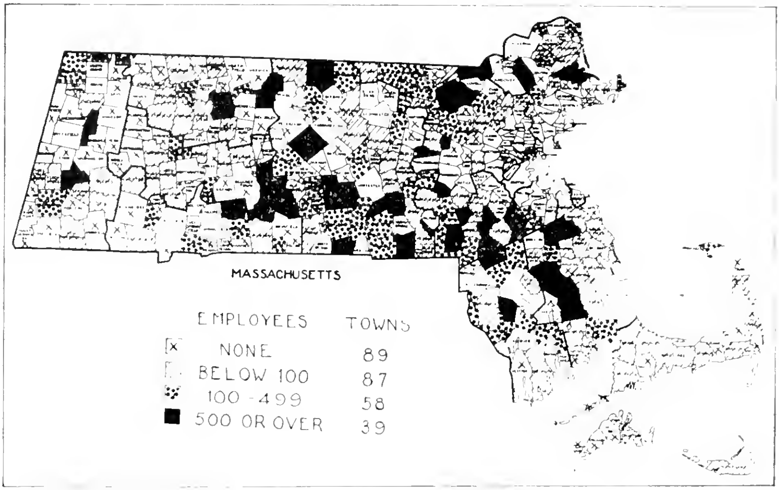
The Industrial Factor

The presence of industries in rural communities has a definite effect on local agriculture and land utilization. Under favorable conditions it provides an opportunity for local employment of the farming population and a certain amount of land utilization for residential and part-time farming purposes. The results are of a sustaining nature for local farming if it presents a proper supplement to local land utilization and brings about a desirable balance. The disadvantages that may accrue arise largely from the fact that a number of recent industrial plants in small towns have been operating on an unstable basis, frequently leaving a large number of local people without definite employment. This condition often places a heavy burden on the rest of the population, and especially on those engaged in farming, by the necessity of providing relief and other assistance. The pressure on the going farming business may be exceedingly high, especially when, because of higher taxes, some farms are being abandoned and withdrawn from agriculture.

Historically, it is important, however, to note that traditionally rural communities of Massachusetts have been associated with local industries which in the early period of development fitted into the fundamental conditions of the individual community. A certain balance in the utilization of human and natural resources was created thereby in the interchange of activities between agricultural and industrial pursuits. Over a period of years, the gradual disappearance of local industries in a number of communities has disturbed this balance, with a resulting decline also in farming activities and agricultural land utilization.

Inasmuch as the presence of local industries in Massachusetts towns has played such an important part in agricultural land utilization in the past, it is of immediate consequence to consider what is the situation in the number of local industries at the present time. By combining and analyzing the data obtained from the State Industrial Census of 1938 and from the special survey of local industries made in 1935, and the information supplied by industrial directories, it has been possible to determine the number of industrial employees for all rural towns in Massachusetts.

From the map indicating the number of industrial employees in towns below 10,000 population it appears that, out of a total of 273 towns, 89 or about one-third have no industries at all. In 87 towns, or roughly another third, the number of employees is below 100 in any one town. In the next group of 58 towns, the number of industrial employees ranges from 100 to 500. The remaining 39 towns have more than 500 industrial employees each. The full significance of these data will appear later when they are discussed in connection with agricultural land utilization and other important factors in rural communities.



Map 3. Towns Below 10,000 Population Classified on the Basis of the Number of Employees in the Town Industries

TABLE 9. — GROUP AVERAGES FOR TOWNS BELOW 10,000 POPULATION

	Group 1 Low	Group 2 Middle	Group 3 High
Population per Square Mile, 1940	26.8	100.9	356.0
Percent of Total Area in Woodland, 1941	47.9	67.1	81.2
Percent of Total Area in Improved Land, 1935	6.7	14.2	26.4
Percent of Land Suitable for Agriculture, 1941	29.7	54.0	70.4
Value of Farm Land and Buildings, per Acre, 1935	$37.38	$98.85	$284.57
Size of Farms, Acres, 1935	34.3	64.8	135.7
Cows per Square Mile, 1940	6.1	18.3	35.8
Poultry per Square Mile, 1940	71.5	289.9	911.8
Percent of Farm Land Improved, 1935	21.8	33.0	50.5
Tax Rate, Towns Below 10,000 Population, 1940	$24.06	$31.68	$40.75
Employees—Percent of 1940 Population	.7	4.8	19.0

TOWN GROUPINGS ON THE BASIS OF MAJOR FACTORS IN LAND UTILIZATION

In the preceding discussion general consideration has been given to several important factors which have affected agricultural land utilization in Massachusetts over a period of years. The influence of some of these factors has been naturally more important than that of others, depending on the period of time and the character of individual sections. The areas so far considered have been in terms of counties which in themselves contain a great variety of conditions. This gives, therefore, only a partial picture since in Massachusetts even individual towns present a wide variation, especially in the physical background found within their limits.

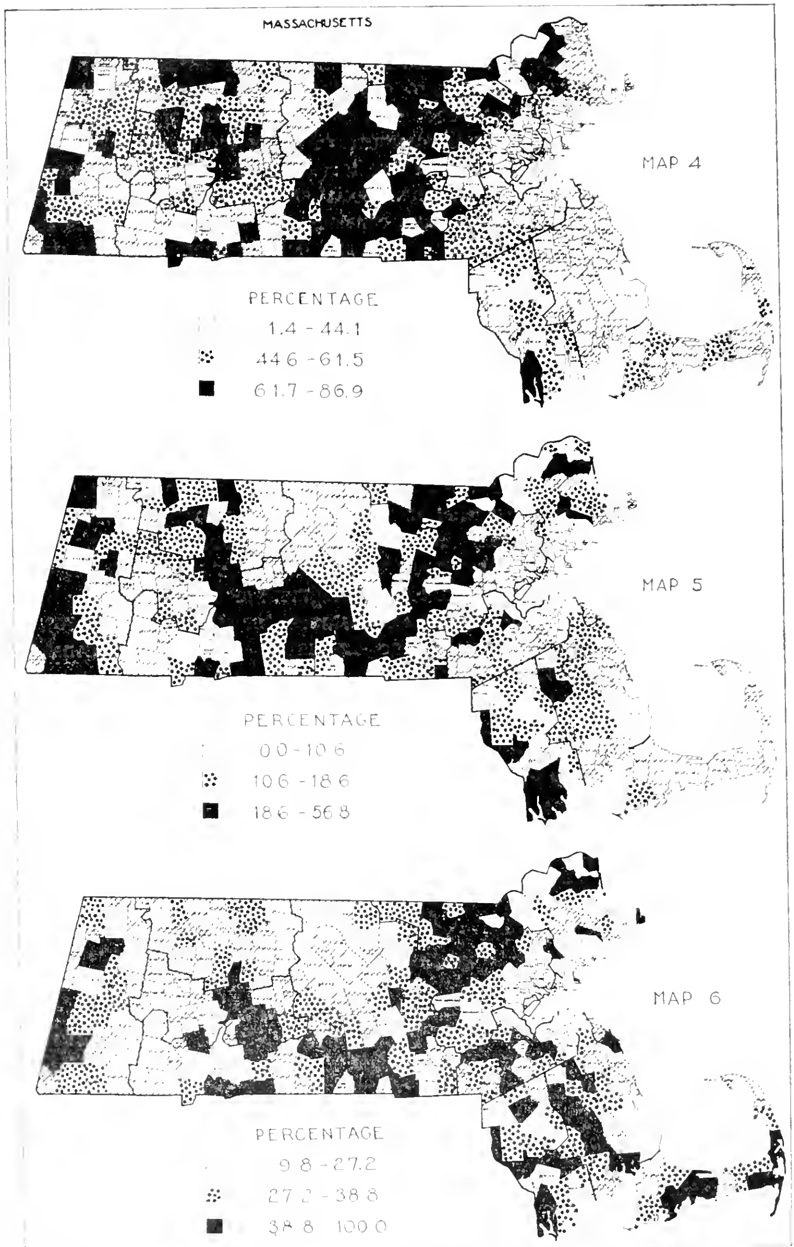
In order to form an adequate picture of land utilization and to explain it in terms definite enough to propose desirable adjustments in any particular com-

munity of the State, a detailed analysis of local conditions is of primary importance. The land utilization survey throughout the State and the analysis of land utilization factors, presented in considerable detail in a series of maps for individual towns, make it possible now to formulate local plans on a definite factual basis. From the data obtained and from the examination of individual communities, it is possible to fix broad classifications of the individual towns in relation to several important factors. These factors cover both vital features in agricultural land utilization and pertinent social and economic influences operating in the communities. On this basis consideration is given by towns to the proportion of woodland, the density of cow and poultry population, the average size of farms, and the percentage of land suitable for agriculture.

From the economic and social point of view land values, density of population, and the amount of industrial employment in various communities are taken into account. For purposes of effective measurement of these characteristics and for subsequent classification of the towns, all the communities in the State (excluding the Island counties) with a population of less than 10,000 have been divided into three groups, each containing the same number of units. The procedure followed was, first to array the towns in ascending order in relation to each item under consideration. In this manner the first group contains one-third of the towns where a certain characteristic is least important, and the second and third groups indicate in their respective order the increasing importance of the factor under consideration. By observing the group into which the town falls in regard to each particular item, it is possible to form a judgment as to the character of the town and its relation to other towns. For instance, the standing of the town in regard to the proportion of improved land, amount of woodland, and density of cow and poultry population will indicate the extent of agricultural land utilization and development in relation to other communities in the State. The relative position of the town in regard to farm land values, if considered with other factors such as location and proportion of improved land, will indicate the extent to which other land uses exert their influence on agricultural land utilization. The intensity of industrial employment indicates the extent to which additional sources of income are available to the town and the amount of land associated with residential and part-time farming developments. The grouping of towns in regard to each item under consideration is presented in a subsequent series of maps.

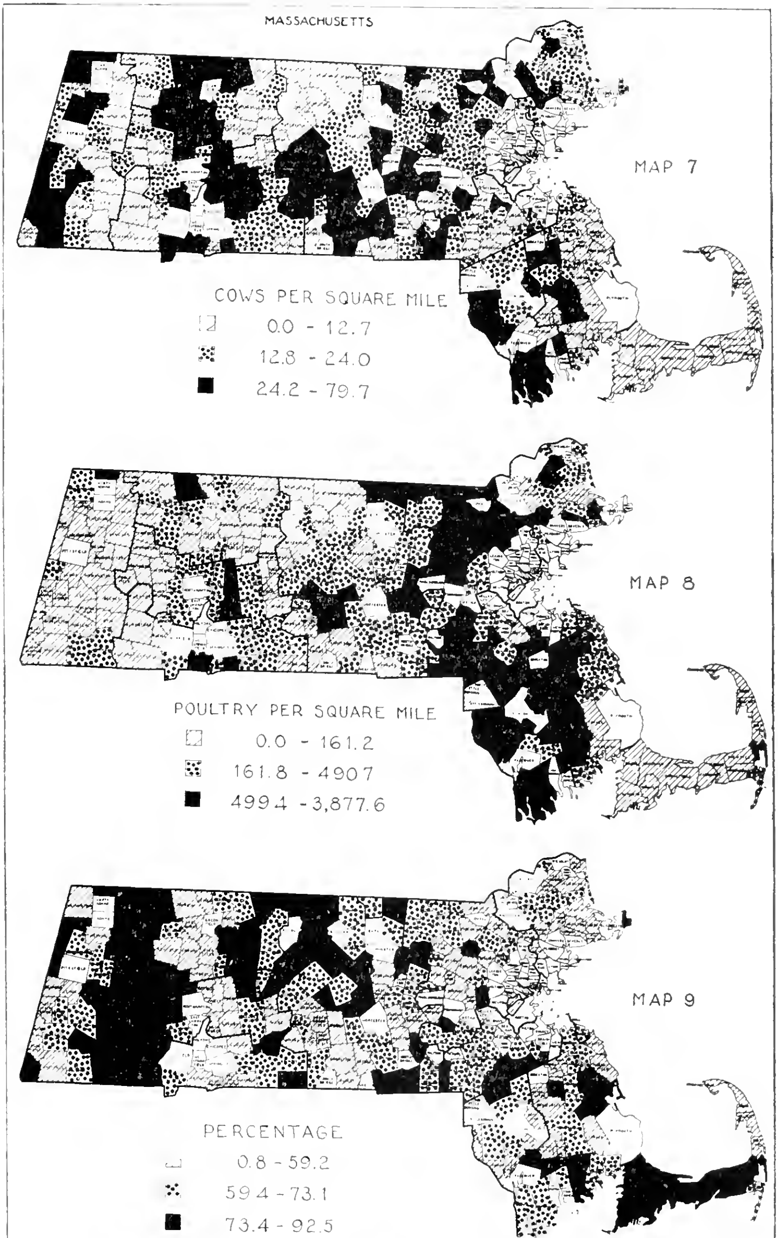
Land Suitability

Land suitability has been determined on the basis of soil and topography. Areas classified as of good or medium quality for agricultural purposes have been combined to form the total amount of land designated as suitable. This designation has no reference to the present use or cover. As a matter of fact, for reasons already discussed in the first part of this report, much of the land suitable for agricultural development and at one time actually used in farming is now devoted to some other use, with most of it under wooded cover. This in itself would prevent these areas from being immediately available for agriculture. However, by comparing the groupings of towns on the basis of land suitability and the amount of improved land it is possible to observe which towns, by virtue of historical or other reasons, have lost their agricultural significance, even though they may rank high on the basis of their physical background. Likewise there are a few towns where a high degree of agricultural land utilization prevails in spite of a rather limited amount of good land to justify such a condition. Nevertheless for the great majority of towns a high degree of coincidence between these two factors will be easily observed.



Towns Below 10,000 Population Classified in Three Equal Groups

Map 4. On the Basis of the Percentage of Land Suitable for Agriculture
Map 5. On the Basis of Percentage of Total Land Area Improved
Map 6. On the Basis of Percentage of Farm Land Improved



Towns Below 10,000 Population Classified in Three Equal Groups

Map 7. On the Basis of Density of Cow Population
Map 8. On the Basis of Density of Poultry Population
Map 9. On the Basis of Percentage of Total Area in Woodland

Proportion of Improved Land

The proportion of improved land is considered both from the standpoint of total town area and in relation to land in farms. Each indicates a different set of circumstances. A high percentage of improved land in the total town area denotes the agricultural character of the town as far as land utilization is concerned. On the other hand, a high proportion of improved land in farms does not necessarily point to the same position of the town in agricultural land utilization. There are a number of towns of a residential and industrial character with only a few farms but with most of the land on these farms being utilized for farming.

Classification on the basis of percentages of improved land in relation to total town area indicates (Map 5) that the group of towns with the lowest proportion of improved land is found in the hilly sections of the Berkshire area, in the northern section of Worcester County with the adjoining towns of Franklin County, and in the Cape Cod region. The proportion of improved area in this group of towns ranges up to 10.6 percent. The small amount of land utilized for agricultural purposes in these towns is due in most cases to the poor quality of the soil or rough topography or both. In the eastern part of the State the primary cause is most often the use of land for purposes other than agriculture or forestry.

The second or intermediate group of towns has a range in proportion of improved area from 10.6 to 18.6 percent; these towns are scattered in various sections of the State. The third group, with the highest percentage of improved land, is represented largely by towns in the western part of Berkshire County, in the Connecticut River Valley, in the southern part of Worcester County, and in the northwestern portion of Middlesex County. Most of these towns have a high degree of land suitability and are primarily agricultural in character.

In considering the grouping of towns on the basis of proportion of improved land in farms it will be observed from the maps that there is substantial coincidence with the groups based on the relation of improved land to total town area. There are, however, a number of exceptions, the most notable being the Cape Cod area, where little land is in farms, but most of it is used with a fair degree of intensity.

DENSITY OF COWS AND POULTRY

The amount of improved land indicates the degree of intensity to which the land is being utilized for crops and improved pasture. Much of the agriculture of Massachusetts, however, is carried on through the medium of imported feed which enables some towns with a low degree of land utilization to maintain considerable numbers of livestock and poultry. Maps 7 and 8 indicate respectively the number of cows and poultry supported by the individual towns per square mile of their territory.

Density of Cow Population

Dairying is the predominant type of agricultural enterprise in Massachusetts and is found in all sections of the State. The major distinctions in the organization of the dairy industry in Massachusetts, going from west to east, lie in the smaller size of farms (Map 7), the declining proportion of pasture land, and the amount of home-grown feed per head of livestock. In considering the grouping of towns on the basis of the density of cow population it will be observed that the greatest concentration is in towns where the proportion of improved land to the total town area is the highest, or in other words, in towns which have already been designated as agricultural on the basis of land utilization.

Density of Poultry Population

In regard to the importance of the poultry industry, the distribution of towns presents a different picture with more emphasis on geographical location. The greatest density of poultry population is found in the eastern part of the State. It is lower in the central part and reaches the lowest level in the towns of Berkshire County. Unlike the situation with the dairy industry, poultry farming, therefore, is largely located irrespective of the suitability of land for cultivation or the proportion of improved land.

Proportion of Total Area in Woodland

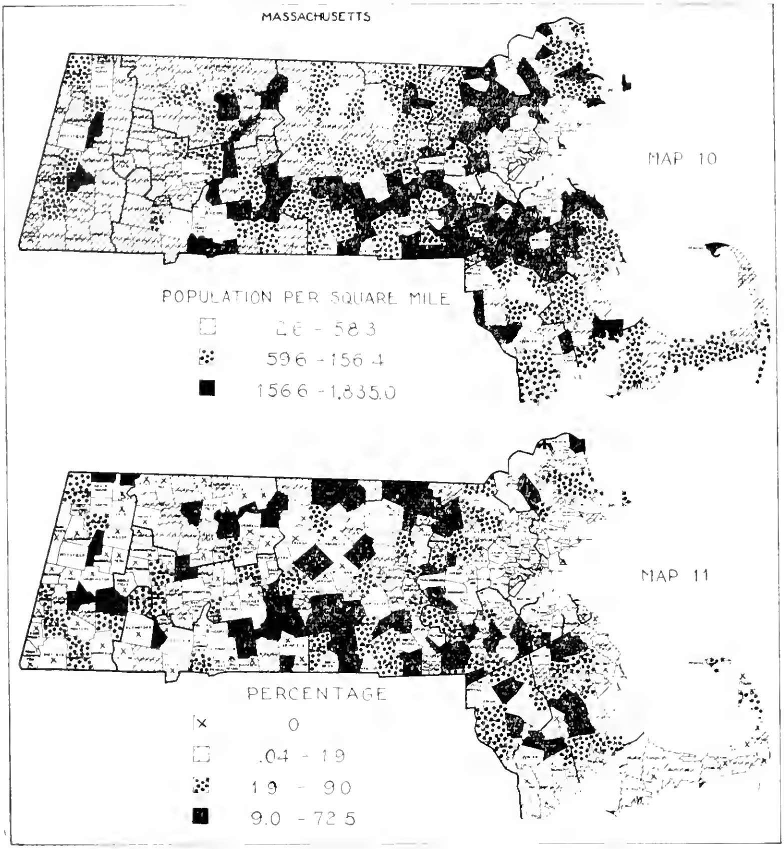
In classifying the towns on the basis of the proportion of woodland, all the areas under wooded cover have been included, whether in farms or not. As already pointed out, trees are the major cover of land in the State and this is illustrated by the fact that in some cases the proportion of woodland exceeds 50 percent of the total area, even in the lowest third of towns. In general, the groupings of towns indicate an inverse ratio to the classification on the basis of improved land. The towns with the highest proportion of improved land show the smallest amount of woodland and vice versa.

The classification of towns on the basis of land suitability, amount of improved land, and density of livestock population deals primarily with factors involved in agricultural land utilization. In order, however, to grasp the full significance of these factors and place them in proper relation to other types of land utilization, it is necessary to take into consideration several major economic and social developments which pertain to the character of the communities.

Density of Population

Coincident with the general decline in agricultural land utilization in a number of Massachusetts communities, there occurred also a decrease in total population. This took place primarily in towns where agriculture and small local industries were the basis of the town's economic development. With the decline or disappearance of these basic activities and no new enterprises to take their place, a general decline set in with a crushing effect on the entire economic structure of the community. In spite of the fact that the total population of Massachusetts more than doubled in the period between 1880 and 1940, there are 101 towns in the State where the population now is smaller than it was at the earlier date. Most of these towns are located west of the Connecticut River Valley, with an additional group in the eastern part of Franklin County and the western scetion of Worcester County. In the eastern part of the State the decline took place in most of the towns of Cape Cod and the two Island Counties.

In considering the three groups of towns segregated on the basis of density of population, as presented on Map 10, it is easy to see that the group at the lower level closely coincides with those towns experiencing a decline in agriculture since 1880. The group with the highest density of population is mostly in the eastern part of the State, although some towns belonging to this class are found in the Connecticut River Valley and around industrial centers in other sections.



Towns Below 10,000 Population Classified in Three Equal Groups

Map 10. On the Basis of Population Density
Map 11. On the Basis of the Ratio of Those Employed in Industry to Total Population

Industrial Employment

It has already been pointed out that in the past there existed in Massachusetts a very close connection between agricultural land utilization and local industries. Judging by the State Census of Massachusetts, in the middle of the last century practically every community had some industry giving full- or part-time employment to a certain number of local people who ordinarily were also engaged in farming. This well-balanced arrangement has been disturbed over a period of time for a good many towns with the disappearance of local industries. At the present time, 89 towns, or one-third of the total number with a population of less than 10,000, have no industries at all. Only a small number of these towns

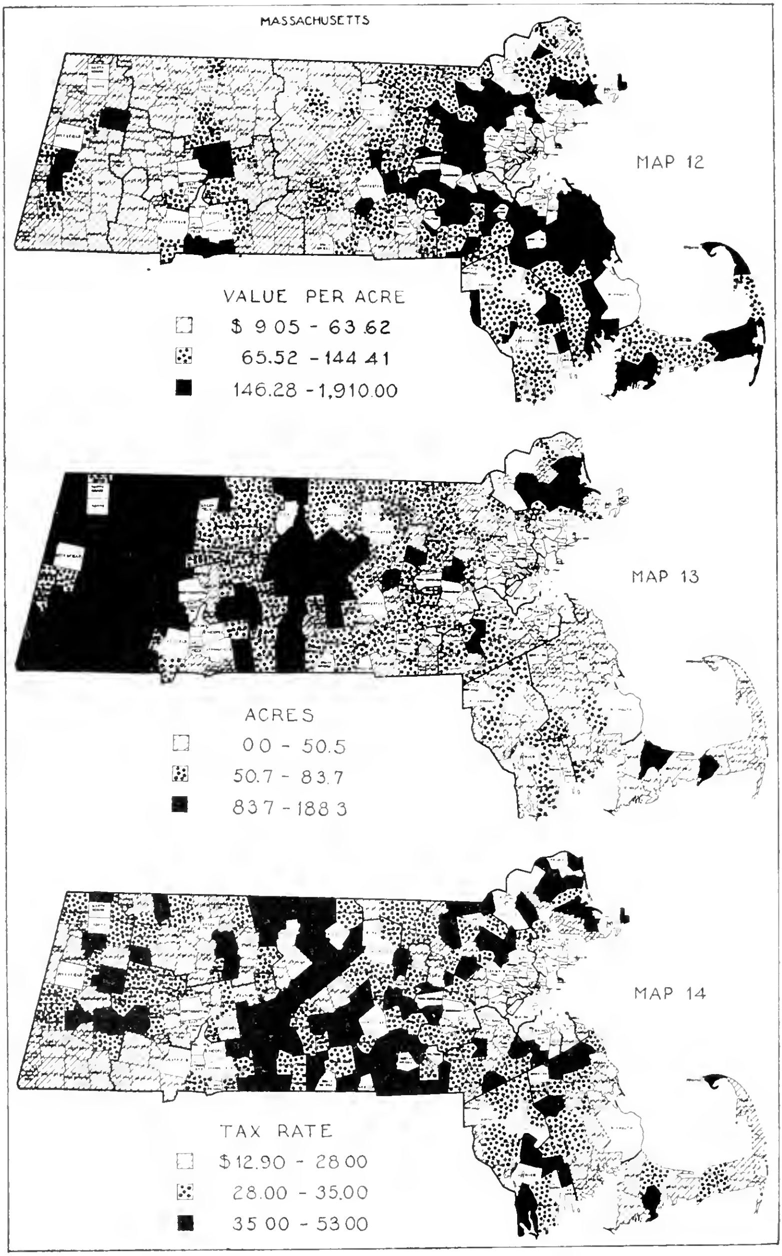
is in the eastern part of the State. Most of them are in the western areas where the main reliance has always been on agricultural land utilization accompanied by extensive areas of woodland. In the remaining 176 towns under 10,000 population where figures for industrial employment at the present time are available, the group classified as the lowest third has so little in the way of industries that it can be practically disregarded as a factor in industrial classification. In the intermediate group the number of industrial employees ranges from 1.9 to 9.0 percent of the total population, with an average just under 5 percent. The towns in this group are scattered throughout the State, although in most cases they adjoin towns with the highest concentration of industrial employment. This upper third group of towns is decidedly industrial in character and is concentrated mostly in the eastern and central parts of the State. From the standpoint of land utilization the existence of established industries in these towns has a definite significance by providing an additional source of income for the town and by involving a certain amount of land use for residential, recreational, and part-time farming purposes.

Land Values

The influence of various factors on land utilization in any community finds its final expression in the prevailing values of land. While from the standpoint of agriculture the value of land should be determined primarily by its productive capacity, in many Massachusetts towns this condition obtains only to a limited extent. In working out the map indicating the division of towns into three groups, the average value of both land and buildings has been employed because of the character of the information available by minor civil divisions. The actual division is therefore on the average value of farm real estate per acre of farm land. In the lowest of the three groups the average value of farm land and buildings per acre ranges from $9.05 to $63.62 with an average for the group of $37.38. The map shows that these towns are located mostly in the western part of the State. Inasmuch as this section is least subject to the influence of more intensive land uses, the farm land values in this area come the nearest to being based on the agricultural importance of the land. The supplementary land uses in this area are largely forestry and less intensive types of recreational developments.

For all the towns in the intermediate group the average value of land and buildings rises to $98.85 per acre. While some of the towns in this group, as in the one preceding, derive their land values solely on the basis of their agricultural importance, most of them, especially in the upper range, definitely show the influence of more intensive uses. This follows both from their location and from the relative density of the local population. The major concentration of the towns in this group is in the western edge of the eastern third of the State and in the Connecticut River Valley.

The third group of towns, with the highest land values, appears in the eastern densely settled area of the State. The values here range from $146.28 to $1,910, with an average for the group of $284.57 per acre. In these towns, agricultural land utilization, with a few minor exceptions like cranberry bogs, is dependent, from the standpoint of land values, upon more intensive uses present or anticipated. In these towns, the interdependence and interrelationship among several major land uses is most apparent and effective. Agricultural land use planning, therefore, can not be carried on adequately in these towns without giving full recognition to the presence of residential, part-time farming, recreational, and industrial land uses. (Table 10)



Towns Below 10,000 Population Classified In Three Equal Groups

Map 12. On the Basis of Average Value of Land and Buildings per Acre of Farm Land
Map 13. On the Basis of Size of Farms
Map 14. On the Basis of the Tax Rate per $1,000 of Valuation

Table 10. — Relative Position of Towns Below 10,000 Population in Three Groups for Eight Different Factors

1—Percentage of land suitable for agriculture, 1941
2—Percentage of total area in improved land, 1935
3—Cows per square mile, 1940
4—Poultry per square mile, 1940
5—Percentage of total area in woodland, 1941
6—Population per square mile, 1940
7—Employees—percentage of total population, 1940
8—Value of farm land and buildings per acre, 1935

The towns are divided into three equal groups for each factor: 1 indicates the "low" group; 2, the "medium" group; and 3, the "high" group; 0 in column 7 means that there were no industrial employees in the town.

Town	1	2	3	4	5	6	7	8
Barnstable County								
Barnstable	1	1	1	1	3	2	1	2
Bourne	1	1	1	1	3	2	1	2
Brewster	1	1	1	1	3	1	0	3
Chatham	1	1	1	2	2	2	0	3
Dennis	2	1	1	1	3	2	0	3
Eastham	2	1	1	1	1	1	0	2
Falmouth	2	2	1	1	3	2	1	3
Harwich	1	1	1	1	3	2	1	3
Mashpee	1	1	1	1	3	1	0	3
Orleans	1	1	1	3	3	2	1	3
Provincetown	1	1	1	1	1	3	2	3
Sandwich	2	1	1	1	3	1	1	2
Truro	1	1	1	1	1	1	0	3
Wellfleet	1	1	1	1	1	1	2	2
Yarmouth	2	1	1	1	3	2	1	2
Berkshire County								
Alford	3	3	3	1	1	1	0	1
Becket	1	1	1	1	3	1	3	1
Cheshire	2	3	3	1	1	2	2	1
Clarksburg	1	1	3	3	3	2	3	1
Dalton	2	2	2	1	2	3	3	2
Egremont	3	3	3	1	1	1	0	1
Florida	1	1	1	1	3	1	0	1
Great Barrington	2	3	3	1	2	2	2	2
Hancock	1	2	2	1	3	1	0	1
Hinsdale	3	3	2	1	2	1	0	1
Lanesborough	2	3	3	1	2	1	0	1
Lee	1	2	3	1	2	3	3	2
Lenox	3	3	2	1	1	2	0	3
Monterey	2	2	1	1	3	1	0	1
Mount Washington	1	1	1	1	3	1	0	1
New Ashford	1	1	1	1	3	1	0	1
New Marlborough	3	3	2	2	2	1	2	1
Otis	2	1	1	1	3	1	2	1
Peru	2	1	1	1	3	1	0	1
Richmond	3	3	3	2	1	1	0	2
Sandisfield	1	2	1	2	3	1	0	1
Savoy	2	1	1	1	3	1	0	1
Sheffield	3	3	3	1	1	1	0	1
Stockbridge	3	3	2	1	2	2	1	3
Tyringham	1	2	2	1	2	1	1	1
Washington	1	1	1	1	3	1	0	1
West Stockbridge	2	3	3	1	1	1	2	1
Williamstown	3	3	3	2	1	2	2	1
Windsor	2	2	1	1	3	1	0	3
Bristol County								
Acushnet	2	2	3	3	2	3	2	3
Berkley	2	2	2	3	1	2	0	2
Dartmouth	2	3	3	3	2	2	1	2
Dighton	2	2	2	3	2	2	3	2
Easton	2	1	2	3	2	3	2	3
Freetown	2	1	1	2	3	1	3	2
Mansfield	2	2	2	3	3	3	2	2
Norton	2	2	2	3	2	2	3	2
Raynham	2	2	3	3	1	2	2	2
Rehoboth	1	2	3	3	2	1	2	2
Seekonk	1	3	3	3	1	3	2	3
Somerset	2	3	3	3	1	3	1	3
Swansea	1	3	3	3	1	3	2	2
Westport	3	3	3	3	2	2	0	2
Essex County								
Boxford	3	2	2	2	2	1	0	2
Essex	1	2	2	3	1	2	0	3
Georgetown	3	1	1	3	2	2	2	2
Groveland	3	3	2	3	1	3	1	3
Hamilton	2	2	1	2	1	2	0	3
Ipswich	1	2	2	1	1	3	2	2
Lynnfield	2	2	2	2	1	3	1	3
Manchester	1	1	1	2	1	3	1	3
Merrimac	3	2	2	2	2	3	2	2
Middleton	2	2	3	3	1	3	2	2
Nahant	1	1	1	1	1	3	0	3
Newbury	1	3	2	2	1	2	1	1
North Andover	3	2	3	1	2	3	3	2
Rockport	1	1	2	1	3	3	2	3
Rowley	1	1	2	2	2	2	2	2
Salisbury	1	2	2	2	1	2	3	2
Topsfield	3	3	3	1	1	2	1	3
Wenham	2	3	2	3	1	2	0	3
West Newbury	3	3	3	3	1	2	0	2
Franklin County								
Ashfield	3	2	3	2	1	1	1	1
Bernardston	3	3	3	2	2	1	1	2
Buckland	2	3	3	2	2	2	1	1
Charlemont	2	2	2	2	3	1	1	1
Colrain	3	2	3	3	1	1	1	1
Conway	2	2	3	1	1	1	1	1
Deerfield	3	3	3	1	1	2	1	2
Erving	1	1	1	1	3	2	2	1

TABLE 10. — RELATIVE POSITION OF TOWNS BELOW 10,000 POPULATION IN THREE GROUPS FOR EIGHT DIFFERENT FACTORS—continued

1—Percentage of land suitable for agriculture, 1941
2—Percentage of total area in improved land, 1935
3—Cows per square mile, 1940
4—Poultry per square mile, 1940
5—Percentage of total area in woodland, 1941
6—Population per square mile, 1940
7—Employees—percentage of total population, 1940
8—Value of farm land and buildings per acre, 1935

The towns are divided into three equal groups for each factor: 1 indicates the "low" group; 2, the "medium" group; and 3, the "high" group. 0 in column 7 means that there were no industrial employees in the town.

Town	1	2	3	4	5	6	7	8
Franklin County—Cont.								
Gill	3	3	3	2	1	2	0	1
Hawley	1	1	1	1	3	1	0	1
Heath	3	3	2	1	3	1	0	1
Leverett	2	2	1	1	3	1	2	1
Leyden	3	2	3	1	1	1	0	1
Monroe	2	1	1	1	3	1	3	1
Montague	2	2	2	1	3	3	3	1
New Salem	1	1	1	1	2	1	0	1
Northfield	1	2	3	1	2	1	0	1
Orange	1	1	2	2	2	3	3	1
Rowe	1	1	1	1	3	1	0	1
Shelburne	2	3	3	2	1	2	3	1
Shutesbury	3	1	1	1	3	1	0	1
Sunderland	3	3	3	2	2	2	0	2
Warwick	2	1	1	1	3	1	0	1
Wendell	2	1	1	1	3	1	0	1
Whately	3	3	3	2	1	1	0	2
Hampden County								
Agawam	3	3	3	3	1	3	2	3
Blandford	1	1	1	1	3	1	0	1
Brimfield	2	3	2	2	2	1	0	1
Chester	1	1	1	1	3	1	2	1
East Longmeadow	3	3	3	3	1	3	0	3
Granville	1	1	1	1	3	1	1	1
Hampden	1	3	2	2	1	1	0	1
Holland	3	2	1	1	3	1	0	1
Longmeadow	2	2	1	2	1	3	0	3
Ludlow	1	3	3	2	1	3	3	2
Monson	1	2	2	2	2	2	1	1
Montgomery	1	1	2	1	3	1	0	1
Palmer	1	2	2	2	3	3	3	1
Russell	1	1	1	1	3	2	3	1
Southwick	3	2	3	2	2	1	0	2
Tolland	1	1	1	1	3	1	0	1
Wales	3	1	1	1	3	1	3	1
Wilbraham	3	3	2	2	2	2	3	2
Hampshire County								
Amherst	3	3	3	3	1	3	1	3
Belchertown	2	3	3	2	2	2	0	1
Chesterfield	2	1	1	1	3	1	2	1
Cummington	2	2	2	1	3	1	0	1
Goshen	3	2	2	1	3	1	0	1
Granby	2	3	3	3	1	1	0	2
Hadley	3	3	3	2	1	2	0	3
Hatfield	2	3	2	2	1	2	1	3
Huntington	1	2	2	1	3	1	2	1
Middlefield	1	1	2	1	3	1	0	1
Hampshire County—Cont.								
Pelham	1	1	1	2	3	1	2	2
Plainfield	2	2	1	1	3	1	0	1
Southampton	2	2	3	2	2	1	1	2
South Hadley	2	3	3	2	1	3	2	2
Ware	2	3	2	1	1	3	3	1
Westhampton	1	1	2	2	3	1	1	1
Williamsburg	2	2	3	2	3	2	3	1
Worthington	2	1	1	1	3	1	0	1
Middlesex County								
Acton	3	3	2	3	1	2	2	3
Ashby	2	2	2	3	2	1	1	1
Ashland	2	1	2	2	3	3	3	3
Ayer	2	2	2	2	2	3	1	2
Bedford	2	3	3	3	1	3	1	3
Billerica	3	2	2	3	2	3	2	3
Boxborough	3	3	2	3	2	1	0	2
Burlington	2	2	1	3	2	3	1	3
Carlisle	2	1	2	3	3	1	0	2
Chelmsford	2	3	3	3	1	3	2	3
Concord	3	3	2	3	1	3	2	3
Dracut	3	3	3	3	1	3	2	2
Dunstable	3	3	2	3	2	1	0	2
Groton	3	3	1	2	2	2	3	2
Holliston	3	2	2	3	2	3	2	3
Hopkinton	2	2	1	2	2	2	2	2
Hudson	3	2	2	3	2	3	3	3
Lincoln	2	3	2	2	2	2	0	3
Littleton	3	3	3	3	1	2	3	3
Maynard	3	2	2	3	1	3	3	3
North Reading	2	1	2	3	1	3	1	3
Pepperell	3	3	3	3	2	2	3	2
Sherborn	2	2	3	3	2	2	1	3
Shirley	3	3	2	2	2	3	3	2
Stow	2	3	3	3	1	2	2	2
Sudbury	2	3	2	3	1	2	0	3
Tewksbury	2	3	3	3	1	3	0	3
Townsend	3	1	1	3	3	2	3	2
Tyngsborough	2	2	2	3	2	2	1	2
Wayland	2	1	2	2	1	3	0	3
Westford	2	3	2	3	2	2	3	2
Weston	2	1	2	2	3	3	1	3
Wilmington	3	1	1	3	2	3	1	3
Norfolk County								
Avon	1	1	3	3	3	3	2	3
Bellingham	2	1	3	3	3	3	3	2
Canton	1	1	1	1	2	3	3	3
Cohasset	1	1	2	2	2	3	0	3

TABLE 10. — RELATIVE POSITION OF TOWNS BELOW 10,000 POPULATION IN THREE GROUPS FOR EIGHT DIFFERENT FACTORS—continued

1—Percentage of land suitable for agriculture, 1941
2—Percentage of total area in improved land, 1935
3—Cows per square mile, 1940
4—Poultry per square mile, 1940
5—Percentage of total area in woodland, 1941
6—Population per square mile, 1940
7—Employees—percentage of total population, 1940
8—Value of farm land and buildings per acre, 1935

The towns are divided into three equal groups for each factor: 1 indicates the "low" group; 2, the "medium" group; and 3, the "high" group; 0 in column 7 means that there were no industrial employees in the town.

Town	1	2	3	4	5	6	7	8
Norfolk County—Cont.								
Dover	2	2	1	2	2	2	2	3
Foxborough	2	2	1	3	3	3	2	2
Franklin	2	1	2	3	2	3	3	2
Holbrook	1	1	2	3	3	3	3	3
Medfield	2	2	1	2	2	3	1	2
Medway	2	3	3	3	1	3	2	3
Millis	2	3	2	3	2	3	3	3
Norfolk	2	2	1	3	2	2	1	2
Plainville	2	2	2	3	2	2	3	2
Randolph	1	1	2	3	2	3	2	3
Sharon	2	1	1	2	3	3	1	2
Stoughton	2	1	2	3	3	3	3	3
Walpole	1	2	2	3	2	3	3	3
Westwood	1	3	3	2	1	3	1	3
Wrentham	2	1	1	3	2	3	2	3
Plymouth County								
Abington	1	2	2	3	1	3	3	3
Bridgewater	1	3	2	3	1	3	2	2
Carver	1	2	1	1	1	1	1	3
Duxbury	1	1	1	2	3	2	0	3
East Bridgewater	1	2	3	3	3	3	2	3
Halifax	1	2	2	3	2	1	0	3
Hanover	1	2	2	3	2	3	3	3
Hanson	1	2	1	3	2	3	2	3
Hingham	1	2	2	2	2	3	1	3
Hull	1	1	1	1	1	3	1	3
Kingston	1	1	2	2	3	2	1	3
Lakeville	1	2	1	3	1	2	0	3
Marion	1	1	1	2	2	2	1	3
Marshfield	1	1	1	2	1	2	1	3
Mattapoisett	1	1	2	2	3	2	0	2
Middleborough	1	2	3	3	2	2	3	2
Norwell	1	2	1	3	2	2	1	3
Pembroke	1	1	1	2	3	2	2	3
Plympton	1	2	1	2	3	1	2	2
Rochester	1	1	1	3	3	1	2	2
Rockland	1	1	1	3	1	3	3	3
Scituate	1	2	1	2	1	3	0	3
Wareham	1	1	1	1	2	3	2	3
West Bridgewater	1	3	3	3	1	3	1	3
Whitman	1	2	3	3	1	3	3	3
Worcester County								
Ashburnham	1	1	1	1	2	1	3	1
Auburn	2	2	2	2	2	3	2	3
Barre	3	2	3	2	2	2	3	1
Worcester County—Cont.								
Berlin	2	3	3	3	2	2	2	2
Blackstone	3	3	3	3	2	3	1	2
Bolton	3	3	2	2	2	1	0	2
Boylston	2	1	2	2	2	2	1	2
Brookfield	2	3	3	1	3	2	3	2
Charlton	3	3	3	1	1	2	3	1
Douglas	2	2	1	1	3	2	2	1
Dudley	3	3	3	2	1	3	3	2
East Brookfield	3	3	2	3	1	2	3	2
Grafton	3	3	2	2	1	3	3	2
Hardwick	1	3	3	2	2	1	2	1
Harvard	3	2	2	2	3	2	0	2
Holden	3	1	2	2	3	2	2	2
Hopedale	3	1	2	3	2	3	3	3
Hubbardston	3	1	2	2	3	1	0	1
Lancaster	3	2	2	3	3	2	2	2
Leicester	3	2	3	3	2	3	3	1
Lunenburg	3	3	3	3	2	2	0	2
Mendon	3	2	3	3	2	2	1	2
Millbury	3	3	3	3	2	3	3	2
Millville	2	2	2	2	2	3	0	2
New Braintree	3	3	3	3	1	1	0	1
Northborough	3	3	3	3	2	2	1	2
North Brookfield	3	3	3	3	1	3	3	2
Oakham	3	2	3	2	3	1	0	1
Oxford	3	3	3	2	1	3	2	2
Paxton	3	2	3	3	3	1	0	1
Petersham	1	1	1	1	3	1	0	1
Phillipston	1	1	1	2	3	1	0	1
Princeton	3	2	1	1	3	1	3	1
Royalston	1	1	1	1	3	1	1	1
Rutland	3	2	2	2	2	2	0	2
Shrewsbury	3	2	3	3	1	3	1	3
Southborough	2	3	3	2	1	3	3	3
Spencer	3	3	3	3	1	3	3	2
Sterling	3	3	3	2	1	1	1	2
Sturbridge	3	2	1	1	2	2	2	1
Sutton	3	3	3	2	2	2	2	2
Templeton	2	1	1	1	3	2	2	2
Upton	3	2	1	2	3	2	1	1
Uxbridge	3	2	2	2	3	3	3	1
Warren	3	3	3	1	1	2	3	1
Westborough	3	3	3	3	1	3	2	3
West Boylston	3	3	3	2	1	2	0	3
West Brookfield	3	3	3	2	2	2	1	1
Westminster	3	2	2	2	2	2	1	2
Winchendon	3	1	1	1	3	2	3	1

TYPES OF COMMUNITIES AND THE PROBLEMS ARISING FROM THEIR PATTERNS OF LAND UTILIZATION

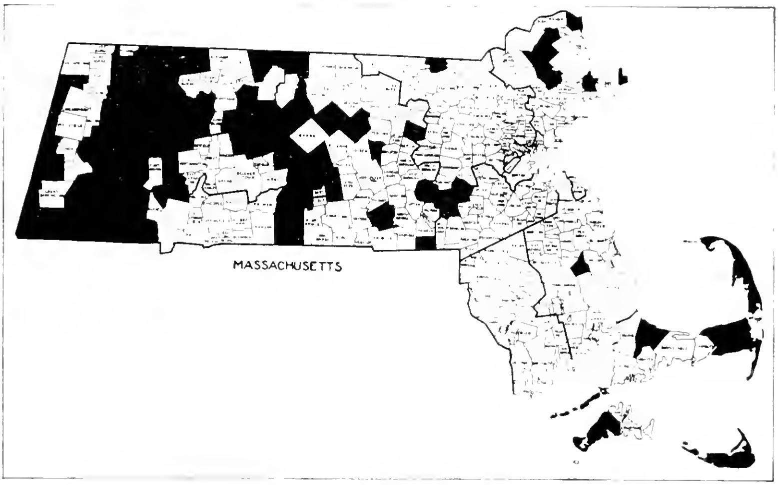
In the preceding discussion the classification of towns has been based on several important factors in land utilization. The extent to which any one of these factors is present in the community and the manner in which it is combined with other factors largely determine the pattern of land utilization in that community. To a certain degree every town in Massachusetts presents a land-utilization picture where two or more land uses exist in some combination. Considering the variety of natural conditions in Massachusetts towns and the diversity in the character of the population present in various localities, it is only natural that agriculture should be closely associated with other land uses. Whether this association has developed in a harmonious and mutually beneficial manner depends on a good many factors of which historical background, physical basis, and activities of individuals are important. Where all these influences have not worked out favorably the town has a definite land-utilization problem. Some of the difficulties in these towns can be removed only over a very long period of time, but in the main a considerable amount of work can be done in the elimination of some of the maladjustments. This presents a real challenge to the various public agencies working in rural areas and to local planning organizations. A great deal can be accomplished towards general improvement by getting well acquainted with the fundamental assets and deficiencies of the community and the important forces which tend to influence the type of land utilization in existence. The interrelationship of various land uses should be thoroughly understood before any plan of action is undertaken. In many communities, for example, with a combination of various land uses, the position of agriculture may be considerably improved by applying assessment and taxation based on an adequate system of land classification. Agricultural land should be taxed according to its productive capacity, thus placing the existing farming on a more stable and permanent basis. This must be clearly recognized because, in many communities where other uses are also important, farming still remains the most basic and fundamental factor in the proper utilization of local natural resources.

Under diverse influences each community in the course of time has developed its own pattern of land utilization, and in order to give an adequate appraisal of local conditions it is necessary to study each town in detail. There are, however, some outstanding characteristics which distinguish the types of communities associated with the existing patterns of land utilization. On this basis, five different types of communities are considered in the light of prevailing combinations of land uses, their problems and needed adjustments.

A. Towns with a low level of agricultural land utilization and lacking other more intensive land uses.

In the general decline of agricultural land utilization in the State, a considerable number of towns that lost in farming never succeeded in regaining their balance and former importance by evolving other land uses and compensating lines of activity. These towns generally have a low density of population which in many cases is scattered over wide areas. The land areas are predominantly under wooded cover with some of them used for extensive recreational purposes. There is only a limited amount of good land available for agriculture and even this includes much that is either stony or sandy or too wet. The topography is mostly rough, except in a few level sandy or marshy areas. Because of the absence of any appreciable development of more intensive land uses, the values of

land are at a low level and the rate of taxation is high. It is not difficult to identify these towns by observing the above characteristics in the series of maps classifying the major factors in land utilization. The main problems in these towns are either connected with fiscal difficulties arising from the necessity of maintaining local institutions, or related to the field of conservation of natural resources. The difficulty in maintaining local institutions follows from the insufficient amount of productive taxable property and from large overhead expenses in servicing a small local population. Examination of the town maps prepared in connection with the land-use survey indicates that in many of these towns there is a considerable amount of scattered settlement. That means high costs for the maintenance of roads and for supplying all the necessary public facilities. (Map 15)



Map 15. Towns with Smaller Population in 1940 than in 1880 (Black areas)

One of the most valuable contributions which can be made to some of these towns by land-use planning committees is to work out the procedure for the gradual elimination of scattered settlements and for the consolidation of public services. By closing some roads which now service only a few isolated farms and relocating the people involved, it will be possible to effect considerable savings. Another possible means of cutting expenditures will be found in co-operative ownership or joint leasing by several adjoining towns of the equipment needed for servicing roads and for other important town activities. In some western states, effective use is being made of rural zoning, whereby isolated areas or those unfit for agricultural cultivation are being gradually closed to agricultural settlement. The application of this measure may be of great advantage also in some rural areas in Massachusetts. It must be recognized, however, that with variations in soil and other natural conditions even over very small areas and with diversity in the types of farming practiced side by side it may be difficult to draw definite lines, except in a few well-determined sections. Any other measures that may be adopted by the towns to reduce their expenditures will relieve the pressure of heavy taxation on agricultural land in the better areas of these towns.

On the positive side, to increase local sources of revenue, attention should be drawn to the possibilities of new types of land utilization, primarily in the field of recreation, for which these towns possess a fairly attractive background. Something can be accomplished also through the promotion of inherited skills of the local population, such as the handicraft industries which were so prominent in the past and which have great promise, judging by the experience of certain communities in Massachusetts and other New England states.

In some towns it is evident that even very thorough measures of economy and search for new opportunities will not alleviate to any appreciable extent the condition of the local farming population nor reduce the contribution from the Treasury of the Commonwealth to local needs. In such cases it may be to the benefit of all concerned to discontinue the independent existence of the town as a political unit, by merging or some other rearrangement.

Inasmuch as the predominant type of land use in the entire group of towns under consideration is woodland, it is essential to secure the best results from the utilization of local forest areas. In the past these woodlands provided substantial returns both to the farmers by supplying their home needs and to the community as a whole through the maintenance of local wood-working industries. At present comparatively little is obtained in either of these directions and the forests in these towns are generally neglected. In the interest of the conservation of natural resources a managed system of forest practices is of primary significance for these areas. Through public ownership some of the wooded areas in these towns have become a part of the State forests and are receiving the benefit of better management and protection. This is also being realized through the establishment of town or community forests. A new hope for better conservation methods in the extensive forest areas remaining in private ownership is a forest taxation bill recently passed by the Legislature. Under this bill the taxation of timber is postponed until actual harvesting, thus preventing the destructive practice of premature cutting.

B. Communities with favorable agricultural background but experiencing difficulties in maintaining balanced conditions because of recent removal of industrial or other enterprises.

The type of towns to be considered in this classification has retained a considerable amount of its agricultural land utilization and, moreover, has been in a rather prosperous condition until very recent years because of the presence of industries or other supplementary enterprises. Most of the difficulties in these towns have arisen within the last fifteen or twenty years and were caused largely by a decline in industrial activity or by the disappearance of the industrial enterprises which were an integral part of their economy.

Communities of this type will be found mostly in the central part of the State. From the standpoint of the adopted classification, they occupy an intermediate position in their land suitability and the proportion of improved land, and have a high position in the tax rate division. The most important factor, however, that singles them out is the decline of population that has recently occurred, mostly since the early twenties. In a way this type of town is undergoing the same process as the first group in the early stage of their decline. Because of this early historical start in the decline of the latter some important adjustments have already taken place. For one thing, because of an early realization of the dwindling resources, local expenditures if not radically curtailed at least were not expanded, as was the case in towns more favorably situated.

The towns of this second group have yet to undergo the painful process of readjustment unless new sources of income are found to help restore the former

balance. Failure to take decisive measures before the situation becomes critical has a most distressing effect on local agriculture. With the decline of other sources of taxable income and a dwindling population, local agriculture is called upon to carry a heavier burden of taxation. As a result some farming is driven out, thus placing the remaining farmers in a still less advantageous position. To relieve the situation and restore the necessary balance, careful and active planning by all local interests is of vital importance. If new industries can be brought in to use the existing facilities, the solution may be near at hand. These industries, however, must be stable in character and blend well with local resources and conditions. The situation will only be aggravated by attracting a type of business which after a short period of activity folds up and leaves in its wake greater maladjustments than existed prior to its appearance. In addition to industrial opportunities, attention should be turned to possible new land uses which will supplement and fit into the local pattern of land utilization. These may include part-time farming, residential, and recreational projects in conformity with the local natural background.

C. Communities predominantly agricultural in character with favorable physical background and fairly high utilization of agricultural resources.

In a number of towns with good soil and generally favorable physical conditions agriculture has always been a primary activity, and even in the period of transition there has been no important diminution in the use of land for agricultural enterprises. The only vital change that has occurred from time to time has been in the character and type of farming adjusted to newly developed conditions. On the maps presenting the classification of towns on the basis of several factors, the communities under consideration will be found in the groups having a high proportion of improved land and of land suitable for agriculture, while land values will be found primarily in the intermediate group.

Industrial activity, if present at all in these towns, has never acquired a dominant position in the local economy and whatever fluctuations have occurred have not been potent enough to disturb seriously the predominantly agricultural character of the communities. There has not been much increase in the local population for a long time, nor has there been any appreciable decline. The whole trend is characterized by comparative constancy and stability.

With the main reliance on agricultural land utilization as a source of income, local institutions have been generally maintained on a steady basis in conformity with the productive capacity of the towns. Inasmuch as farming remains the primary type of land utilization in these communities, the kind of problem that arises is in connection with the successful conduct of the farming business. This involves efficient organization and operation of farming enterprises and conservation practices intended to preserve the productive capacity of the soil. While the first has been given considerable attention over a period of years through the educational activities of the agricultural extension service, soil conservation as a systematic practice has come into prominence only recently. With wider application of soil conservation practices these towns will have better assurance of the continued existence and stability of their farming to the extent that it depends on healthy conditions of local natural resources.

D. Communities with a high or fair proportion of good land, but with declining agricultural land utilization due primarily to high land values caused by more intensive land uses, present or expected.

This group of towns is concentrated largely in the eastern densely settled section of the State or in proximity to the coast where recreational land uses are an important factor. At one time a considerable amount of profitable farming was carried on in these towns in relation to the amount of land of suitable quality. With the growth of large industrial centers and especially of the Boston Metropolitan Area, there has been an increasing demand for land for residential purposes in the nearby rural towns. This demand has been greatly accelerated with the construction of new roads and the perfecting of automotive traffic. While much of the land in these towns has already been developed for residential or recreational purposes, a considerable amount is being held as a potential area for more intensive uses. Some of this land is still in farming, but a great deal has gone out of farming and is now under predominantly wooded cover. As a result of all this, whatever farming remains in these communities is under constant pressure from high land values, high taxes, and the additional disadvantage of the high cost of local labor. Much farming in these areas is waging a losing battle against all these odds. It is true that these high-priced agricultural land areas have some advantages. For one thing, the market is near at hand, with possibilities of higher prices and lower costs of transportation. But to take full advantage of his location the producer must sell his output at retail. The most logical and almost imperative channels for sale are routes of regular customers, roadside stands, or similar direct approaches to the consumer. If advantage of these possibilities is not taken or can not well be taken, the results are mostly disastrous to the producer. It means that additional commercial farming units will be compelled to go out of business and former agricultural areas will either be employed in more intensive types of land utilization or added to already large sections of woodland. In general, fundamental economic and social forces are working definitely against the feasibility of continuing commercial farming in these areas. If agriculture here is preserved and continued it will be largely on a part-time farming basis.

In the meantime, some of these towns face very difficult problems in agricultural land use adjustments. Measures must be taken at once to alleviate the critical position of the producers and at the same time to prevent waste in the utilization of local natural resources. It is questionable in many cases whether the good land withdrawn from agriculture and allowed to grow into brush will ever be used for the more intensive purposes for which it is ordinarily held. A partial solution of the problems in agricultural land utilization for these areas could be achieved by a judicious classification of land, whereby the land actually used for agriculture would have the benefit of lower assessment and taxation. This would be an important step in alleviating the condition of local farmers and would enable them to keep the land in agricultural production.

E. Communities with a fairly balanced system of land utilization, where decline in agricultural land use has been accompanied by the development of other land uses with favorable effects on local farming.

This type of community is found in various sections of the State and represents a combination of agriculture with one or several other uses of land, such as recreational, part-time farming, industrial, and residential. As distinguished from the preceding group, the more intensive use of land in these communities has pro-

ceeded in an orderly way favorable for agriculture and the entire system of local land utilization. It provides a desirable supplement to local agriculture and has added to rather than detracted from the stability of local farming and better utilization of natural resources.

On the basis of the fundamental factors, the communities in this group will be found largely in the intermediate class, where various characteristics are present in a moderate degree rather than in extremes.

In the Berkshire region and the sections adjoining it on the east, the combination is largely agriculture, forestry, and water areas with various recreational uses. In the central part of the State, it is mostly agriculture with part-time farming, industrial, and residential land uses. In the eastern part of the State all these combinations are repeated, strongly influenced by land uses other than agricultural, with especial intensity of recreational factors in the vicinity of the coast.

The presence of more intensive types of land utilization in these towns tends to raise land values somewhat, but not to an extent that is definitely detrimental or prohibitive to agriculture. On the other hand, the town benefits from the existence of diversified sources of assessment which allows a more equitable distribution of the taxes necessary to cover the expense of local government. Without the necessity of paying too high taxes, local agriculture is provided with superior services which are made possible by the economic conditions arising from a high level of utilization of local natural resources. Additional advantages accrue also to the farming population from better local markets provided by the presence of the varied elements in the town population.

When a desirable balance of various land uses is present in any community the main problem is to assure the stability of that condition and to prevent serious disturbance of the existing pattern of land utilization. Such disturbance may take place with the knowledge and encouragement of the local government and people, if they do not sufficiently appreciate the necessity of maintaining the established balance among the existing land uses. Some towns, for instance, go out of their way to attract new industries or to foster the development of residential or intensive types of recreational land uses. Even if the new enterprise is of great benefit to the town at the time of introduction, this does not necessarily mean that it will be beneficial in the long run. As a matter of fact, the experiences of some towns with hastily projected new industries or residential and recreational schemes, clearly indicate the necessity of applying a rigid test to any such undertaking from the standpoint of the influence it may have on the economy of the town and the utilization of its natural resources.

Some undesirable developments, however, take place in spite of the opposition and resistance of local communities. A case in point is the recent experience of certain communities, especially in the eastern part of the State, with land occupancy for part-time farming and residential purposes by the unemployed and other families in distress. In most cases such people have added heavily to local expenditures for social services without contributing anywhere near the equivalent to the town treasury. The results may be disastrous to the town economy and to the established balance in the utilization of local natural resources. The case of these people is a grave social problem to challenge our best effort. It can hardly be left to the responsibility of individual communities with its threat of total disruption of healthy and thriving rural towns.

SUMMARY AND CONCLUSIONS

1. The classification of land on the basis of soil and topography indicates that half the total area of the State is suitable for agricultural utilization.

2. The percentage of agricultural suitability varies from nearly one-third in Barnstable County to slightly less than two-thirds in Worcester County.

3. In 1880, before the decline in the agricultural land area set in, 41 percent of the State area was represented by improved farm land. In 1940 this proportion had declined to 15 percent.

4. The major local land-use factors responsible for the decline of improved farm land relate in varying degrees to changing types and systems of farming; soil erosion and deterioration; non-resident land ownership; disappearance of town industries; and growth of residential, recreational, commercial, and other more intensive uses of land.

5. Non-resident ownership of about one-third of all land in rural towns has contributed to the increasing amount of land under wooded cover.

6. Of the total State area, nearly two-thirds is under wooded cover. The highest proportion (nearly three quarters) is in Barnstable and Berkshire Counties; the lowest (slightly more than half) in Essex and Middlesex Counties.

7. In the towns below 10,000 population, 89 have no existing local industries. In 87 of the remaining 184 towns, local industries provide employment for less than 100 persons in any one town.

8. The demand for more intensive uses of land has affected farming through higher land values and taxes.

9. The average value per acre of farm land and buildings is $37 in the lowest third of the towns below 10,000 population; in the highest third, the average is $284 per acre.

10. From the standpoint of land-use pattern and land-use adjustments needed, five types of rural towns are indicated in Massachusetts:

A. Towns characterized by predominantly poor land, declining population, limited agricultural land utilization, and extensive areas under wooded cover.
Major adjustments needed: Extension of public ownership of forest land, elimination of isolated settlement, development of recreational facilities, possible discontinuation of the town as an independent political unit.

B. Towns with a fair agricultural background experiencing recent dislocation in local industries.
Major adjustments needed: Realignment of town expenditures, fuller utilization of land resources for agriculture and other uses, rehabilitation of industrial opportunities.

C. Towns with favorable physical background and with well-rounded agricultural land utilization.
Major adjustments needed: Conservation of soil, better adaptation of crops, and better care of woodlots.

D. Towns with declining agricultural land utilization as a result of expansion in more intensive uses of land.
Major adjustments needed: Prevention of increase in area of idle land held for speculative purposes, primarily by more equitable taxation of land used in agriculture.

E. Towns with a balanced system of agricultural and other land uses.
Major adjustments needed: Maintenance and improvement of local conditions through farsighted policies of local people and their planning agencies.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 388 FEBRUARY, 1942

Annual Report

For the Fiscal Year Ending November 30, 1941

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION -- 1941

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

Competitive Factors Influencing the Supply of Market Milk and Cream in Massachusetts. (A. A. Brown and Mabelle Booth.) The manuscript on the Production and Price of Milk in the Springfield-Holyoke-Chicopee Milkshed has reached the final stages of editing. This report is the third in a series pertaining to the shed and represents a tentative appraisal of the forces affecting the origin of the milk supply. The principal one appears to be the system of pricing f. o. b. the market. In secondary markets this type of pricing underlies the inefficiencies in transportation which in turn are probably a cause of the non-economic pattern of milksheds. A reasonable correction would seem to be a shift to pricing f. o. b. the farm.

An Analysis of Selected Merchandising Practices in the Fruit and Vegetable Industry. (A. A. Brown and Mabelle Booth.) A record of the operations on the Boston Regional Produce Market in 1941 has been secured in addition to that of 1940. Cursory examination indicates that conditions were similar in both seasons. Most of the farmers using the market are small operators. The majority of them used it only a few times during the season. A few of them, however, are large operators who supplied the bulk of the produce.

The financial situation of the market corporation is its chief obstacle to growth. Because of this, the fixed plant remains undeveloped. Until a greater degree of permanency is assured, improvements such as store and storage facilities are not probable. Lack of these facilities keeps wholesalers and jobbers away from the market; shipped-in produce is not generally available; buyers go to other markets where complete supplies may be had.

Crop and Livestock Enterprise Relationships to the Farm Business in Massachusetts. (C. R. Creek.)

Vegetable Growing in Bristol County, Massachusetts, in 1940. Records of the farm business were obtained on 22 specialized vegetable farms and on 10 livestock–vegetable farms for 1940. Since the season was more nearly normal than in 1939 in regard to yields and prices for vegetable crops, the 22 specialized farms showed a net cash return over cash operating expenses ranging from a gain of $8,022 to a loss of $270 per farm.

Average returns for the livestock–vegetable farms were lower than for the specialized vegetable farms in 1940. The livestock enterprises showed a return over costs but the important crops—potatoes, sweet corn, and cabbage—were relatively unprofitable in 1940. On many farms income from the livestock enterprises prevented a loss in net returns.

Recommendations for improved practices and management were made on the basis of results obtained from this study. Many small farms have incurred unnecessary losses in recent years chiefly because of poor management and lack of adjustment to changing conditions in vegetable growing and marketing.

Results of this study were published in Mimeograph FM8 in October 1941, under the title, "Vegetable Growing in Bristol County, Massachusetts, in 1940."

Two Years of Vegetable Growing in Bristol County, Massachusetts—1939 and 1940. The farm records for 1939 and 1940 on the specialized vegetable farms were studied to determine the reasons for the increased returns in the latter year. Net cash return averaged $1777 per farm in 1940 compared to a loss of $4 in 1939. Records were obtained for 20 of these 22 farms in both years.

Higher yields and higher prices for four important crops were chiefly responsible for the higher returns. The acres of crops per farm were practically equal, cash farm expenses increased only 20 percent over 1939, but sales of produce increased 60 percent. Yields and prices increased greatly in 1940 over 1939 for iceberg lettuce, cucumbers, green beans, and early tomatoes. Yields were maintained for sweet corn, late tomatoes, cabbage, and potatoes, but prices were lower particularly for cabbage and tomatoes.

Net cash returns for the livestock vegetable farms were slightly lower in 1940, with an average of $1399 compared to $1453 in 1939. Number of cows and acres of crops for sale were the same in both years, but the average size of poultry flocks increased slightly. Unprofitable crops such as potatoes, cabbage, and sweet corn were responsible for the lower returns in 1940.

Budget analyses were made for a small and a large specialized vegetable farm and for a livestock-vegetable farm to show expenses, income, yields, and prices for the two years. Diversification of the farm business on the latter farm was discussed in relation to the more uniform returns in both years. Preliminary recommendations for improving the farm business were made on the basis of this two-year study.

Results of this study were published in Mimeograph FM9 in October 1941 entitled, "Two Years of Vegetable Growing in Bristol County, Massachusetts—1939 and 1940."

Diversification of the Farm Business. In response to a request from the Subcommittee on Diversification, of the Essex County Rural Policy (Land Use Planning) Committee, a summary was made of farm records from previous studies to show the effect of various types of diversified farm businesses on farm organization and net returns.

Diversity by the processing and distribution of farm products was shown to be very profitable in the case of retail dairy farms from the 1936-37 study of dairy farm management. With the same number of cows per herd, but receiving 7 cents per quart extra for milk, the retail farms had net cash returns four times greater than the specialized wholesale dairy farms. In the case of poultry farms for 1937 this method of diversification was not so profitable. The retail farms had larger flocks, and more eggs were sold at a price 6.5 cents per dozen higher; but net cash returns and farm income were almost equal to those on the specialized wholesale poultry farms. Cash operating expenses were too high and the spread from wholesale to retail price was too narrow for extra profitable operation of these retail farms.

Wholesale dairy farms with a fruit or vegetable enterprise were generally more profitable than the specialized dairy farms. Because of unfavorable price relationships in 1936, the combination of dairy and poultry enterprises was less profitable.

Another method of diversification on poultry farms was the selling of hatching eggs or baby chicks in addition to market eggs, broilers, and fowl. The more intensive of these hatchery farms with 30 percent of cash receipts from the sale of baby chicks and pullets showed the highest net returns of any group in the 1937 study. The wholesale egg farms with some hatching egg and baby chick business were the next most profitable, although the price received for market eggs was lowest. Largest size of laying flock, highest egg production per hen,

and a balanced farm business in the growing of flock replacements were contributing factors to high farm returns.

A balanced or diversified farm business will tend to produce a net return year after year in contrast to high returns and losses on specialized farms. In general a diversified farm business is to be desired, although not all farms of this type are profitable.

Labor Saving Methods and Practices on Massachusetts Farms. (C. R. Creek.)

Harvesting and Packing Iceberg Lettuce. The results of this study on vegetable farms were published in Mimeograph FM5, February 1941. Diagrams of packing shed equipment and layout were included as well as descriptions and discussions of various methods of harvesting and packing.

Harvesting and Packing Tomatoes. This study was published as Mimeograph FM6 in March 1941 and contained descriptions of methods and practices in harvesting and packing tomatoes in different types of containers for various markets. Diagrams of packing equipment such as conveyor belts, tables, and trays are included, plus time data on the efficiency of different methods.

Harvesting and Packing Celery. This study was published as Mimeograph FM7 in May 1941 and supplements a previous description and analysis of packing operations on farms producing celery. Information on equipment and practices in the field work of harvesting celery and a diagram of the packing shed layout for the handling of celery and carrots was included.

Rural Credit in Massachusetts. (A. H. Lindsey and Sargent Russell.) During the year, 273 survey records of 1940 farm operations were taken covering 10 towns in 5 counties of the State. Analysis has not been completed but preliminary conclusions are as follows: (1) The best incomes can be obtained by farmers when they combine non-farm work, such as retailing of their produce, selling grain or machinery, or working off the farm, with their farm operations; (2) In 1940 poultry paid better than dairy, and dairy better than vegetable; (3) Farmers on the whole know where to borrow money at reasonable rates; (4) Farmers borrow as little as possible and although many could use more capital they have restricted their borrowing, not because the money isn't available, nor because their credit standing isn't satisfactory, but because difficulties of repayment outweigh the advantage of increased income due to the investment; (5) In spite of what appears to many as a chronic low income for farm operators, farmers do continue to accumulate an estate in Massachusetts; (6) Tenancy (100 percent rented farms) is low, part ownership and part rent occurs on more than a third of the farms; (7) About two-thirds of the farms have mortgages, and on about one out of every three mortgaged farms the mortgage amounts to over half of what the farmer estimates his farm is worth; (8) The ability of the operator is probably the most important variable in farm operation. The better operators achieve greater success primarily because they have: (a) Good size of business, (b) efficient use of labor, (c) above average crop and livestock production, and (d) good balanced use of all resources (diversity).

Land Tenure in Massachusetts. (A. H. Lindsey and Edward Collins.) The United States Census does not give a complete picture of land tenure in Massachusetts. The 6 percent of tenancy reported by the Census refers to leased whole farms. Our survey shows that another 31 percent of farm owners rent land in addition to their own. This may be properly termed "field renting."

Six percent of the farms available for lease is not sufficient to provide opportunity for prospective owners to use farm tenancy as a "rung" in the agricultural ladder in achieving ownership. The most popular way of earning an equity for the purchase price of a farm was to work as an industrial laborer.

The practice of field renting enables Massachusetts farmers to enlarge their farm business and thus to increase their family income. A loss of these areas would reduce individual farm business to an uneconomic size. Rented fields which are under cultivation usually are satisfactorily maintained but practices are not equal to those on owned land. Conservation practices on rented hay and pasture land were much poorer than on owned land. Eighty-five percent of rented fields were used for hay or pasture. Nine out of ten of the field-renting leases were oral as compared to two out of three where whole farms were rented. Of the part owners who were renting fields, 97 percent received no supervision or direction from the land owners regarding the use of the land.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Tobacco Projects. (Walter S. Eisenmenger and Karol J. Kucinski.)

Brown Root-Rot of Tobacco. Experience has shown that the presence of high amounts of lignin in the crop preceding tobacco is generally associated with the presence of brown root-rot of tobacco. It is well known that the lignin content of plants increases from the seedling stage to maturity. With this in mind, twelve crops—tobacco, artichoke, corn, oats, buckwheat, barley, rape, millet, rye, wheat, sudan grass, and sorghum—were all sown at the same time, and one third of the area of each was plowed under at three different stages of maturity of the plants. Tobacco was planted on all areas the following year.

When those plants having a relatively high lignin content, such as sudan grass, sorghum, corn, millet, rye, barley, and oats, were plowed under at maturity, the tobacco grown on these plots the following year had lower yields and lower crop indexes than tobacco grown following the same plants plowed under before they reached maturity. With those plants low in lignin, such as tobacco, artichoke, and rape, the stage of maturity of the plant did not produce the same effects as in the case of the high-lignin plants.

The Effect of Additions of Plant Tissue to Tobacco Land. A corn crop preceding tobacco is injurious to the following tobacco crop. In order to find out whether this injurious effect is due to the presence of abnormal amounts of fibrous tissue or to the removal of nutrients consequent on the growth of the corn, corn stover, in pieces about one inch long and in amounts comparable to that usually grown on a given area, was applied to soil which was to be planted to tobacco. A decrease in both yield and quality of the tobacco crop resulted.

These results are no doubt traceable to the high lignin content of the corn stover applied, because it is generally known that organic matter of this sort has a tendency to lower the available nitrogen in the soil to which it is applied.

Tobacco Experiments with Application to Soil of Commercial Organic Materials. It has been suggested that the source of organic compounds might possibly determine the yield and quality of the subsequent tobacco crop. Sugar, carbon (charcoal), dry skim milk, and starch were the materials selected for comparison. They were applied at the rate of two tons to the acre. A fifth plot, to which nothing was added, was included as a check.

There was little difference in the action of these different materials. The applications of charcoal or carbon gave the highest yield, as was anticipated from the appearance of the crop in the field; but the quality of this tobacco lowered the crop index value.

The Absorption by Food Plants of Chemical Elements Important in Human Nutrition. (Walter S. Eisenmenger and Karol J. Kucinski.) Some plants have the ability to take up certain chemical elements from the soil in amounts greater than normal, depending both on the ion involved and on the species of plant.

In previous trials, an increase in the amount of magnesium, sodium, potassium, and chlorine added to the soil resulted in increased intake by the plant. In the present experiments, sodium, potassium, and magnesium were compared with calcium; and phosphate and sulfate were compared with chlorine, bromine, and iodine, in this respect.

The increased intake of potassium, sodium, or magnesium, due to the addition of these ions to the soil, was more pronounced than the increase in calcium resulting from the addition of similar chemical quantities of calcium. Also, the percentage increase of chlorine, bromine, and iodine in the plants when these elements were added to the soil was higher than that of sulfur or phosphorus when similar chemical quantities of these anions were added.

This indicates that those elements which are more abundant in sea water than in soil water are the ones which can be introduced into plant tissue with little difficulty. In some respects it would seem that our land plants have not fully adjusted themselves to a land environment.

The Intake by Plants of Elements Applied to the Soil in Pairs Compared to the Intake of the Same Elements Applied Singly. (Walter S. Eisenmenger and Karol J. Kucinski.) Cabbage, lettuce, beans, and celery were grown on plots to which various elements had been added, in pairs, in quantities known to be excessive but not toxic. Chemicals compounds, used in all possible combinations of two, supplied calcium, potassium, and sodium at the rate of 250 parts per million of soil and lithium at the rate of 100 parts per million. The exceeding toxicity of lithium to plants necessitated application at the lower rate and at a considerable time before planting. The calcium intake by cabbage, celery, and lettuce was decreased when either sodium or potassium salts were applied with the calcium. The potassium intake was increased in this combination. The lithium intake was decreased when potassium was applied with the lithium. The potassium intake was decreased somewhat when plants were grown on a combination of potassium and sodium.

Magnesium Requirements of Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) Various species of plants have been grown on a plot known to be deficient in magnesium. There is little evidence to indicate a reason for the varied reactions of different plants to the scarcity of magnesium ions in the soil. Different members of the same family react differently. Sudan grass shows no symptoms, nor does timothy; but regular field corn becomes chlorotic, and hybrid sweet corn scarcely sets any seed. Pumpkin vines show distinct chlorosis; watermelons do so only at maturity.

There is evidence now that plants may suffer from the lack of this element, yet may not show any chlorosis or lack of chlorophyll formation. Strawberry plants do not become chlorotic, yet new runners are formed more abundantly and the strawberry row is wider where magnesium is applied, while the row becomes narrow where no magnesium is applied. The very common garden weed, purslane (*Portulaca oleracea*), called by the farmer "pussley," forms a thick mat where magnesium was applied and ceases to grow, except in rare instances, where the soil is deficient in magnesium. If a plant can be found, it is not chlorotic. Apple leaves from trees on magnesium-deficient soils are not chlorotic, but areas of the leaves become dark brown and eventually die, much like the leaves from a potash-deficient plant.

On areas of the plot where lime was applied, the sugar content of the fruits was increased in some instances. This was true of blueberries and grapes, but not of watermelons.

The Absorption and Excretion of Potassium and Calcium by the Roots of Barley in Different Solution Media and Changes in pH. (Walter S. Eisenmenger and George Wenzel.) Determinations were made of the absorption and excretion of potassium and calcium, by (barley) plants and excised root systems of barley, from and into one-salt solutions of different concentrations, and into distilled water. A study of the changes in hydrogen-ion concentration of the solutions was also included. The salts used were acid potassium phosphate (KH_2PO_4), and calcium nitrate ($Ca(NO_3)_2$). The length of the experimental period was 72 hours in all tests.

The intensity of absorption and excretion increased with the length of the experimental period. In general the absorption increased rapidly after the first 24 hours, while the excretion increased slowly throughout.

The reaction of the media was never stable in the presence of live root systems. The pH values increased during the daylight hours and decreased somewhat during the night. The continual change of pH values was, undoubtedly, tied up with absorption and excretion phenomena of electrolytes, but to state that the degree of change was absolutely proportional to the rates of absorption and excretion would imply the exclusion of buffer action and other controlling factors.

The proportion of absorbable ions absorbed during a given period decreased as the concentration of these ions in the solution decreased. In this way plants can adapt themselves, to a considerable extent, to solutions of low concentration.

For the first two days potassium was more firmly held by the roots than calcium, after which calcium was excreted in larger amounts, but no considerable excretion of either was observed. The excretion of ions into salt solutions was greater than into distilled water.

An equivalent absorption and excretion of calcium and potassium did not take place, except for extremely short periods.

The results with excised roots show that roots alone are not capable of a uniform absorption of ions.

Attention is called to the fact that energy exchanges are involved in the processes of absorption and excretion. Permeability and osmosis alone are inadequate to explain these phenomena in the living plant.

Sunflowers and Their Possibilities. (Karol J. Kucinski and Walter S. Eisenmenger.) This year's growing season was an exceptionally good one for sunflowers, which grew to maturity and formed very large seed heads. Seedings of one seed per hill every 18 inches in 36-inch rows produced a yield of over two tons per acre of well-formed large seeds. This yield is much larger than that obtained in past years, indicating that a good corn-growing season is also a good sunflower season. At the current wholesale market price of sunflower seed the value per acre is about \$225 to \$250. This crop would seem to have great possibilities if grown commercially, even on some of our lands which have a high per acre valuation. Since it is somewhat difficult during this present national emergency to import from abroad as much sunflower seed as is necessary, it might be feasible for some of our farmers to grow the crop commercially.

The oil obtained from sunflower seed is very high in content of vitamins A and D, but it is used in this country primarily as a drying oil in paints. In eastern continental Europe the peasant population has always eaten the seed. It has been thought by some scientists that this seemingly habit-forming practice of eating the sunflower seed is an instinctive effort on the part of the individual to supplement his usual deficient diet with the high nutritive contents of the seed.

Soil Conservation Research Projects. (Karol J. Kucinski and Walter S. Eisenmenger.)

A Study of the Physical and Chemical Properties of Wind-Blown Soils. Only certain types of soil in Massachusetts are normally affected by wind. The object of this study is to determine whether there is any relation between the physical-chemical properties of these soils and their susceptibility to wind erosion. Soils from wind-eroded and non-wind-eroded areas have been examined for their physical and chemical properties, such as mineral and organic colloidal fractions, plasticity, hygroscopicity, mechanical analysis, heat of wetting, heat of conductivity, capacity of absorption, and such other soil properties as are deemed of value. The effect of chemical and physical charges in soil, brought about by the addition of fertilizer, lime, or organic matter, has been studied by means of a small wind tunnel. Preliminary tests were sufficiently satisfactory to warrant the construction of a larger wind tunnel with certain modifications which should make it more suitable for the purpose.

Experimentation with Topsoil Removal. (In collaboration with Arthur B. Beaumont.) In order to measure the effects of loss of topsoil on yield, the topsoil (to plow depth) was totally removed from one plot with a bulldozer, while an adjacent plot was left undisturbed as a check. Spring wheat and white sweet clover were grown on fertilized and unfertilized portions of these two areas.

The increases in yield due to fertilization were significant on both areas. However, the decreases in yield due to topsoil removal are alarming. With spring wheat, the decrease in yield where the topsoil had been removed was 63 percent on the fertilized plot and 91 percent on the unfertilized. With white sweet clover, the results were even more extreme: where topsoil had been removed, there was 81 percent decrease in yield on the fertilized plot and total crop failure (100 percent decrease) on the unfertilized plot. These results show the value of the topsoil and the loss to the farmer if his topsoil were totally removed at one time. Under normal conditions only a small part of the topsoil is removed each year by erosion, and the farmer is not so conscious of his loss.

Nature of Soil Erosion in Massachusetts. (Arthur B. Beaumont and Karol J. Kucinski.) Accelerated water erosion of Massachusetts soils is widespread but of slight to moderate intensity. However, cultivation of steep slopes through a long period has caused the removal of the entire original topsoil in places and its accumulation at the foot of slopes within comparatively short distances from the point of origin. The character of the soils is important as affecting the nature of the erosion. Being of medium texture and low in colloidal matter, they have low suspensibility in water. A preliminary examination of important soil types gave dispersion ratios ranging from 9.3 to 15.3 with most of them below 11.0. Because of the low suspensibility of the soils, they are deposited as soon as the velocity of the water carrying them is slightly lessened. Streams in this section rarely run muddy, and then only at times of high flood.

The pictures on page 53 illustrate (1) the difference in the suspensibility in water of Merrimac fine sandy loam, an important soil of the Connecticut Valley, and Memphis silt loam, an important soil of the Mississippi Valley; and (2) the depth of topsoil accumulated by sheet erosion of a cultivated Massachusetts slope.

Experimentation with Historical "Soil-Test Plots." (Walter S. Eisenmenger and Karol J. Kucinski.) Fifty-one years ago a series of plots was inaugurated to study the effects on the soil and crops of a long-time fixed-fertilizer program. The purpose was to find out the fertilizer needs of the soil tested. Results of these tests published about twenty years ago showed "that fertilizer needs are

determined as much by the farming system followed and the kind of crops grown as they are by the type of soil being farmed."

Since that time these plots have been used for experiments with fruit trees, following the original system of fertilization. The fruit trees have now been removed, leaving a field with limed and unlimed portions of plots which for the past fifty years have had applications of nitrogen, potash, and phosphoric acid, singly and in various combinations. The check plots have been left unfertilized during the entire period. Preliminary observations during the past year have shown that the fertility level of all the plots is much higher on the limed than on the unlimed portions. The unlimed portions of the check plots showed crop failures and indications of nutrient deficiences.

It is the intention to continue this study with the view of observing more carefully the various nutrient deficiencies singly and in combination as they appear in the various crops to be grown on this area.

Potato Variety Trials. (Ralph W. Donaldson, Walter S. Eisenmenger, and Karol J. Kucinski.) Based on yields of marketable size, the ranking of potato varieties grown in plots at the college during the season of 1941 were Sequoia, Earlaine No. 2, Green Mountain, Russet Rural, Katahdin, Houma, Irish Cobbler, Red Warba, Sebago, and Chippewa.

Soil Nitrates Lower pH Reactions. (Ralph W. Donaldson, Walter S. Eisenmenger, and Hrant M. Yegian.) A marked depression of pH reactions which occurred in potted soil as nitrates formed and accumulated was mentioned last year in reporting "the effect of fineness of limestone on soil reaction."

Results of a similar trial in progress now, covering a 12-month period, substantiate the previous findings. In this later trial oats were successively grown on a duplicate series of limed and unlimed soil, in an attempt to remove by plant assimilation the nitrates which develop. Both the cropped and the uncropped soil of any given treatment first exhibited similar reactions except for slight variations dependent upon ammonia development. When nitrates developed, however, the uncropped soils dropped about .7 of a pH below corresponding cropped soils, depending upon the relative amounts of nitrates present. This situation prevailed within limed and unlimed treatments.

Since the product of organic matter decomposition is ultimately nitrates, which under some conditions may accumulate in the soil solution and cause a lowered pH reading, this factor may be important when recommending lime for sensitive crops like potatoes and tobacco. A field sample which shows high nitrates after harvest may give a pH reading about .5 lower than a sample taken during the active growing period of the crop when nitrates are being absorbed. For example, it is conceivable that a potato soil during the active growing period of the crop may show low nitrates in the soil solution and test pH 5.5; yet when tested after harvest, with nitrate accumulated, it may test pH 5.0, for which a light lime application might (wrongly) be suggested. Whether such differences occur under field conditions at least merits consideration.

Borax Trials on Several Crops. (Ralph W. Donaldson, Walter S. Eisenmenger, and W. G. Colby.) Applications of borax to established stands of alfalfa have been continued on more than 20 farms in the State. Both spring and fall applications at 25 and 50 pound rates have been compared, with no evidence at all of injury from the higher rates. In fields where alfalfa "yellows" appeared this season, borax applied prior to this spring effected marked control. This was evident also in single treatments of 25 pounds per acre applied in the fall of 1939, indicating, thus far at least, a two-season carry-over from treatment. The effect of borax applied in the spring was less marked in controlling yellows on the crop which

followed. A marked deficiency of normal rainfall occurred following application of the borax. Evidence that borax may contribute to longevity of alfalfa is indicated by plant response to two seasons' applications compared with the check in two fields.

Borax was broadcast at 25 pound rates in strips on a variety of crops growing on six market garden farms. The treatments were made early in May, without regard to planting time and seedling stage. In no case did growers observe any injurious effects from the borax.

Fertilizer containing 20 pounds of borax per ton was drilled in bands at a ton rate on an acre of Cobbler potatoes planted by D. Wilson Smith, Scituate. There were no symptoms of plant injury which could be attributed to the borax.

Oat Variety Tests. (W. G. Colby.) Eleven named varieties of oats, including several of the recently developed, smut-resistant strains, were grown at Amherst during the past season. The results are reported in Control Bulletin 111, Seed Inspection (pages 92-93), where these named varieties are compared with a number of lots of commercial seeds.

The Effect of Arsenious, Arsenic, and Antimony Oxides on Soil and Plant Growth. (Walter S. Eisenmenger and Hrant M. Yegian.) Pot culture studies under greenhouse conditions on the effect of arsenious, arsenic, and antimony oxides on Merrimac fine sandy loam and subsequent crop growth are being continued. Six successive crops, barley and buckwheat alternating, were grown in the same soil in pots during 1939 and 1941. On June 11, 1941, tobacco seedlings were transplanted to these treated pots. The tobacco was harvested November 14, 1941.

Arsenious oxide, 500 p.p.m., retarded the growth of tobacco and prevented blossoming; while 500 p.p.m. with organic matter produced a fully mature, normal plant. Concentrations of 1000 p.p.m. or over of arsenious oxide were very toxic even in the presence of organic matter.

Arsenic oxide, 750 p.p.m. reduced the growth of tobacco and prevented blossoming; 750 p.p.m. with organic matter, however, produced a fully mature, normal plant. Concentrations of 1000 p.p.m. or over of arsenic oxide, with or without organic matter, were very toxic to tobacco.

The arsenic content of a few of the tobacco leaves, stems, and seeds was determined[1] by the micro Gutzeit method, modified according to C. C. Cassil. The results of these analyses may be summarized as follows:

1. At the low concentration of arsenic (240 p.p.m. As) in the soil, the stems and leaves contained 3 to 6 p.p.m. As, while none was detected in the seed.
2. At the higher concentration of arsenic (480 p.p.m. As) in the soil, the stem and leaves contained 12 to 18 p.p.m. As, and no seeds were produced.
3. Indications are that the concentration of arsenic in the tobacco leaves exceeds that in the stems. The number of determinations, however, was not great enough to warrant definite conclusions at this time.

The tobacco plants in pots containing 1500 and 2000 p.p.m. arsenious oxide made no growth during the five-month period. At the end of five months these plants were transplanted to As_2O_3 free soil. While these plants have resumed growth, it is not a normal but a rosette growth. This may be due either to the age of the transplants, short daylight conditions, presence of arsenic in the plant, or to a combination of all these factors.

The antimony oxide treatment did not affect the growth of tobacco at any concentration (250 to 2000 p.p.m. antimony oxide).

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[1]By John W. Kuzmeski, Senior Chemist, Control Laboratory of the Massachusetts Agricultural Experiment Station.

Hybrid Field Corn. (Hrant M. Yegian.) There is a definite need for an early-maturing hybrid field corn for the higher plateau regions of Worcester County and the western counties of Massachusetts. Accordingly, 64 strains of hybrid seed corn were planted for trial during the past season. A few of these strains, which matured in 90 to 100 days, will be tested next season in Athol, Massachusetts, against the local-grown varieties in that region. Last season 180 inbred lines and single crosses were crossed with Wis. (CC4×CC8). Most of these crosses will be tested for early maturity and yield this coming season at the College Farm.

Onion Breeding. (Hrant M. Yegian.) Hybrids between *Allium fistulosum* (type Nebuka) and *A. cepa* (type Ebenezer) were secured in the spring of 1940. All the flowers of two umbels from Nebuka plants were emasculated twice daily for about two weeks and dusted daily with pollen grain from Ebenezer. Of the 230 plants from one of the umbels 80 percent were hybrid between the two species. Only 10 percent of the plants were hybrid from the second umbel. Although there were no apparent morphological differences between the hybrids and the Nebuka at the seedling stage, the hybrid plants could be recognized in the field by their vigor, the semi-circular leaves growing close together, and the color of the bulbs. Some of these hybrids will be treated with calchicine in an effort to secure tetraploids.

Sufficient seed for testing has been produced from a strain of Ebenezer selection that will mature bulbs about two weeks earlier than the valley-grown varieties. Final field tests will be made before the strain is recommended to the growers.

Data from a two-year preliminary experiment show that there is no significant difference between the yield of set onions grown in double rows and those grown in single rows 14 inches apart. Planting sets in double rows 4 inches apart and placing the double rows 24 inches apart would greatly facilitate the use of power cultivators.

Influence of Soil Fertility on Productiveness of Pasture Species. (Walter S. Eisenmenger and Hrant M. Yegian.) It has long been observed that there is a close relationship between the fertility of the soil and the botanical composition of the vegetation growing upon it. It would be of great interest, therefore, to know whether there are specific levels of soil fertility which are required by different species of pasture plants in order that they may thrive and maintain themselves over an extended period.

The data covering one year of preliminary field plot experiment on the effect of four levels of soil fertility on thirteen species of grasses in pure stand warrant the following general statements:

1. That all the species responded to increase in soil fertility.

2. That the species which produced poorly at a low fertility level gave much greater percentage increases in yield at higher fertility levels. Meadow foxtail, for example, produced an average of 0.19 pounds of dry hay in the plots that had no fertilizer, and 0.54 pounds (184 percent increase) in the plots treated at the rate of 1600 pounds of 5-8-7 per acre. On the other hand, meadow fescue, which averaged 0.48 pounds of dry hay in no-treatment plots, produced 0.76 pounds (58 percent increase) at the highest fertility level (1600 pounds 5-8-7 per acre). However, in each of the four levels of soil fertility, the species which produced greater total dry weight in no-treatment plots outyielded the species which produced poorly in no-treatment plots.

3. That the better-producing species were those well adapted to the climate. Apparently temperature is one of the important factors influencing yield. Perennial rye grass and fowl bluegrass did well in cool weather, but during the heat of summer they dried out; whereas meadow fescue, reed canary grass, and orchard grass maintained comparatively well-sustained growth throughout the season.

Experiments at Amherst with Pasture Seeding Mixtures. (W. G. Colby.) For the purpose of studying different strains of grasses and legumes under actual grazing conditions, three series of plots were laid out in 1940, on land which had been brought to a high state of fertility through the liberal use of lime, manure, and commercial fertilizer. Two series of 19 plots each were seeded August 23, 1940, and a third series of 13 plots was seeded April 18, 1941. The same mixtures were included in each series as far as possible. In several instances, limited seed supplies prevented the use of certain mixtures in more than one or two of the three series.

The object of the experiment was to compare a system of hay–pasture management with pasturing alone and to test summer seeding of pasture mixtures against spring seeding. During 1941, Series I was subjected to four periods of intensive grazing by a small herd of dairy cows: in May, July, August, and October. Series II was first cut for hay before being subjected to three periods of grazing, which coincided with the last three grazing periods of Series I. The spring-seeded series (III) was grazed only lightly at the same time as Series II. The following observations and results deserve mention:

1. Brome grass and meadow fescue (Svalof's early) showed the most promise as being desirable companion grasses for Ladino Clover. The cutting of an early hay crop followed by several periods of intensive grazing appeared to be the most desirable way of utilizing these grasses.

2. Hay types of orchard grass (Scandia and Commercial) as well as the less vigorous pasture types (S26 and S143) did not combine well with Ladino Clover. The orchard grass, irrespective of how it was managed, tended to crowd out the clover even during the first season. This occurred partly because orchard grass grows vigorously throughout the season and partly because it produces tussocks or bunches. Animals grazing on Ladino Clover mixtures with this grass tended to graze the clover growing between the bunches of orchard grass much more closely than they did the clumps of grass, even though the orchard grass was kept in a young, active vegetative growth stage at all times. As a result of preferential grazing, the stand of orchard grass continually improved and the stand of clover deteriorated.

These observations may explain why, in Massachusetts, orchard grass in Ladino Clover seeding mixtures invariably crowds out Ladino Clover, completely, after three or four years and results in a pure stand of orchard grass.

The most promising mixtures using orchard grass were those which included alfalfa and which were cut for hay before being grazed. For this purpose, the later-maturing pasture strains (S26 and S143) were much superior to the hay strains. There is a real need for a hay strain which will mature from a week to ten days later than do any strains now available.

3. The hay–pasture system of management rather than pasture alone appears to have excellent possibilities as a way of utilizing a number of these early maturing grasses (brome, meadow fescue, orchard) not only in producing a good early hay crop but also in providing excellent feed for midsummer grazing. In these experiments, about two tons of dry hay were cut to the acre in the middle of June, followed roughly by three quarters of a ton of dry herbage as grazing the latter part of July, about the same quantity again late in August, and another half ton early in October.

4. Observations on palatability indicated that timothy ranked first among the grasses, followed in order by brome grass, meadow fescue, red top, orchard grass, and tall fescue (Alta strain). Alfalfa, red clover, and alsike, although quite palatable as young plants, became less palatable than Ladino Clover as the plants became older and developed woody stems. The woody, unpalatable stem growth of alfalfa is a serious handicap to the use of this plant for grazing purposes.

5. A good stand of alfalfa was obtained in all of the hay–pasture mixtures (Series II), but only weak stands were obtained when an early period of grazing took the place of a crop of hay (Series I). Apparently alfalfa must be allowed to become well established before grazing is begun.

6. Bird's-foot trefoil, under the condition of these experiments, showed no promise whatsoever.

COOPERATIVE TOBACCO INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture in Cooperation with the Massachusetts Agricultural Experiment Station

C. V. Kightlinger, U. S. D. A., in Charge

Black Root-Rot. (C. V. Kightlinger.) Black root-rot is one of the most common diseases of tobacco, and probably the most important disease of Havana Seed and shade tobaccos in the Connecticut Valley at the present time. The disease is recognized generally as being highly important on the basis of losses caused by moderate to heavy infections which are easily recognized as black root-rot. Its importance is not so generally recognized when losses are caused by light to moderate infections, largely because of the tendency to accept the low yields as a matter of course instead of attributing them to specific causes, and also because black root-rot is not always easily recognized in cases of light infections, even though they may be sufficient to cause low yields. It is reasonably certain that black root-rot causes light to moderate damage to tobacco in the Connecticut Valley much more generally than is commonly recognized at the present time.

An effective and convenient method of controlling the disease would mean much to the tobacco growing industry. The disease and the conditions under which it occurs are of such a nature, however, as to make resistance to the disease the most feasible control method after soil conditions favorable to the disease have become established; and the use of resistant strains, even before soil conditions favorable to the development of the disease have become established, would permit greater range in fertilizing practices, particularly in the use of lime, than is otherwise advisable, which would often promote the production of better tobacco. Consequently the attempt to develop strains of Havana Seed which are more resistant to black root-rot and more acceptable in type, quality, yield, and certain other characteristics, is being continued. The importance of the disease and the prospects of eventual success seem to justify the continuation of the project.

The plan as it is being worked at the present time is two-fold. In the first place, selections of Havana 211, which is itself moderately to highly resistant to black root-rot under Connecticut Valley conditions but which is not entirely acceptable in type, quality, and certain habits of growth, have been made to improve the strain in type and date of maturity. In the second place, new strains have been produced by crossing strains of Havana Seed which are resistant to black root-rot but not entirely acceptable in type and quality, with strains of common Havana Seed which are not resistant to black root-rot but are acceptable in type and quality, in the hope of obtaining new strains which embody the desirable features of both parents.

Tests of the selections of Havana 211 and of the crosses have been made, and are being made, in the greenhouse and in the field, to determine their value. Some of the selections of Havana 211 show improvements over the original strain in certain characteristics, but little if any improvement in resistance to

black root-rot or in habits of growth. Earlier maturity, which was greatly desired, was not obtained in any of the selections of Havana 211. Some of the selections from the crosses possess sufficient resistance to yield well under black root-rot conditions in the Connecticut Valley, and also show distinct improvements in important characteristics of type and habits of growth, including earlier maturity. Some of these selections are as early maturing as the strains of common Havana Seed which were used in making the crosses. They seem, also, to be superior to either parent in some important characteristics such as shape of leaf and size of veins. These particular strains deserve more testing to determine their full resistance to black root-rot and also to determine the permanency of the improvements in type and habits of growth which have been manifested so far. It seems reasonably certain, however, that definite progress has been made.

Brown Root-Rot. (C. V. Kightlinger.) Brown root-rot causes some damage to tobacco in the Connecticut Valley at the present time and probably would cause much more damage if it were not that the circumstances under which the disease ordinarily occurs are now known and are avoided in large measure in present practices of growing tobacco in the Connecticut Valley. The practices of not rotating tobacco with crops known to produce soil conditions favorable to the development of brown root-rot and of growing tobacco continuously after tobacco for as long a time as may be possible are applicable in the control of the disease where the acreage of tobacco is being maintained or reduced somewhat, as has been the case in the Connecticut Valley during the last few years. This method of control, however, is restrictive and is not always convenient to follow even under present circumstances, but the rather dilligent application of the practice has reduced the prevalence and severity of the disease so that it has been of minor importance economically in the Connecticut Valley during the last several years.

Brown root-rot may become more prevalent and injurious in the Connecticut Valley in case of an increase in acreage of tobacco, because of the necessity of using additional land which, on account of previous cropping, may be in a condition favorable to the development of the disease. If this occurs, it will contravene the only measure for the control of brown root-rot of tobacco which is generally recognized at the present time as being applicable to field use. Therefore, a measure which would control brown root-rot of tobacco satisfactorily under varied circumstances and which would be convenient to use on considerable acreages would mean much to the growing of tobacco in the Connecticut Valley in the event that the acreage is increased. Such a measure would be useful also under present circumstances, especially if it would permit rotation of tobacco with other crops in general.

With this situation in mind, experiments were begun in 1939 to obtain further information on the relationship of soil fertility conditions to the development and to the control of brown root-rot of tobacco. One purpose in particular is to study the effect of certain soil treatments on the fertility levels of the soil and to study the effect of different degrees of fertility of the soil on the occurrence of brown root-rot of tobacco following the crops used in the experiment. It is desired especially to learn whether brown root-rot will develop in tobacco which is grown continuously after tobacco under low fertility conditions of the soil. And finally, in case brown root-rot of tobacco develops as a result of these experiments, another purpose is to study means of hastening recovery.

The arrangement and procedure of the experiments designed to determine whether low fertility of the soil may promote the development of brown root-rot of tobacco, consists of four sets of six one-twentieth acre plots in which tobacco, corn, millet, rye, clover, and timothy-red top mixture are grown in the same

manner, except for differences in the use of fertilizers. On two sets of these plots an application of 10-10-10 fertilizer has been made each spring at the rate of 3000 pounds per acre to the plots planted to tobacco, and 2000 pounds per acre to the plots planted to the other crops, in a manner suitable for fertilizing each particular crop. On two other sets of plots no fertilizer has been used, except nitrate of soda which has been applied to all plots alike at the rate of 400 to 500 pounds per acre, to aid in reducing the fertility level of the soil in these plots. The crops were all harvested and removed from the plots each year according to regular farming practices. In an additional experiment on a quarter-acre plot considerably removed from the other experiments, tobacco is being grown continuously after tobacco without any fertilizer at all being used. No results can be reported at this time.

The control phase of the experiment is contingent on the outcome of the other phase; consequently the details of the control phase are not given here.

Soil Treatments for Tobacco Seedbeds. (C. V. Kightlinger.) Damping-off diseases and weeds are troublesome in tobacco seedbeds in the Connecticut Valley. Consequently treatments for their control are important.

Experimental work to test the effectiveness of spring and fall treatments of seedbed soil by steaming and with formaldehyde, and of fall treatments with chlorpicrin and with calcium cyanamid, was begun in 1940 and continued in 1941. The seedbed used for these tests had been prepared especially for the purpose by inoculating uniformly and heavily with damping-off organisms during the spring of 1940. Evidence that the seedbed was abundantly infested with disease organisms was shown by the damping-off of tobacco seedlings grown during the spring and even into late summer of 1940. Care was taken also to make certain that seeds of the more common weeds of tobacco seedbeds were disseminated evenly throughout the soil.

The steaming was done by the pan method at a steam pressure of about 100 pounds applied for 20 minutes, with the pan kept in place for another 20 minutes after steaming had been discontinued. The spring treatment with formaldehyde consisted of a standard solution made of 1 gallon of formalin to 50 gallons of water, applied at the rate of one-half gallon of solution to 1 square foot of soil surface. The fall treatments were steaming, as described above; formaldehyde solution of standard concentration and double the standard concentration, applied in both cases at the rate of one-half gallon of solution to 1 square foot of soil surface; chlorpicrin, applied at the rate of 2 cubic centimeters per square foot of soil surface, and also at double this rate of application, to a depth of about 4 inches into the soil, by means of commercial applicator commonly used for the purpose; calcium cyanamid, applied at the rate of one-half pound per square yard of soil surface, and also at double this rate. In both cases, the calcium cyanamid was worked into the soil thoroughly, three-fourths of the total amount to a depth of 4 to 5 inches and one-fourth to a depth of about 1 inch. The soil treated with calcium cyanamid and chlorpicrin was of proper moisture content for effective treatment at the time and was moistened daily for several days thereafter. The soil temperature at the time formaldehyde, calcium cyanamid, and chlorpicrin were applied in the fall was 67° F., and changed little for a considerable time following the treatments.

No damping-off of tobacco seedlings occurred during the season of 1941, even in the untreated plots of the seedbed, in spite of the fact that tobacco was seeded at double the usual rate and the bed was watered thoroughly every day, and sometimes oftener, to promote damping-off. The unusually warm, dry weather which occurred during the spring of 1941 was sufficient, apparently, to prevent damping-off in spite of the effort that was made to promote its development.

Consequently the comparative value of the treatments for controlling damping-off could not be determined.

The treatments all gave some control of weeds. There were wide differences, however, in the different treatments and also in different replications of the same treatment, except in the case of steaming, which gave consistently good control in all replications of either the fall or the spring treatments. Some replications of the treatments with calcium cyanamid, chlorpicrin, and double-strength formaldehyde solution applied in the fall gave fairly good control of weeds; but these were largely offset by unsatisfactory control in other replications of the same treatments. Steaming was the only treatment that gave entirely satisfactory control of weeds.

The experiment is being repeated.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

A Study of the Mineral Elements of Cow's Milk. (J. G. Archibald and C. H. Parsons.) During the winter of 1940-41 the possibility of increasing the manganese content of milk by feeding supplemental manganese was investigated. Eight cows in the college herd were divided into two groups of four each, and fed manganous sulfate (1 ounce daily) by the double reversal system. Monthly sampling and analyses of the milk of the individual cows from November through April, showed that, regardless of group or individual, the feeding of the manganese supplement definitely increased the manganese content of the milk. On the average the amount of manganese in the milk of cows receiving the supplement was just about double that in the milk from cows not receiving it. (46.1 gammas of Mn per liter of milk as contrasted with 23.5 gammas per liter). Advance announcement of this finding has been published in *Milk Plant Monthly*, Vol. 30, No. 9, September, 1941.

Investigation of the Merits of Legume and Grass Silage for Massachusetts Agriculture. (J. G. Archibald and C. H. Parsons.) As a result of comparative trials extending over three years with molasses and phosphoric acid as silage preservatives, this station has discontinued the use of phosphoric acid as a preservative. The reasons for this are:

1. Molasses silage has been definitely more palatable to milking cows than phosphoric acid silage.
2. Molasses costs somewhat less, even when the much smaller amount of phosphoric acid required is taken into consideration.

Work this past year with grass silage has centered chiefly around its effect on milk flavor in contrast with the effect of corn silage. Part of the herd was fed grass silage and another part corn silage, and the schedule was reversed at mid-season. Individual milk samples from all cows milking at the time have been taken for a period of three days in each month from November through April and judged for flavor. There are some discrepancies among the results, and the differences are not very marked, but in general the grass silage has produced milk with a higher flavor score and with less incidence and persistence of the common off-flavors. Individual off-flavors most reduced when grass silage was fed were malt, bitter, rancid, and oxidized in the order named.

A Study of Urea as a Partial Substitute for Protein in the Rations of Dairy Cows. (J. G. Archibald.) This project has been actively conducted throughout the year. Results are available from two years of double reversal trials with eight

cows and from a full lactation period of continuous feeding of urea to eight other cows in comparison with a similar group continuously fed the regular herd ration. Final conclusions cannot be drawn until the second year of continuous feeding of urea to the eight cows, just referred to, has been completed, and until at least a year's results are available from a group of cows more recently put onto a control ration containing no urea. This last phase of the investigation has been included in order to check more closely the adequacy of basal protein levels in the ration. All things considered, to date the urea ration seems to be producing results similar to those obtained on the regular ration.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Nitrification in Soils Containing Plant Residues of High Lignin Content. (James E. Fuller, cooperating with the Agronomy Department.) During the growing season of 1940 thirteen plots were under observation. During the growing season of 1939 one of these plots had remained fallow, and each of the remaining twelve had been planted with a forage crop. There were no duplicates. Then, in 1940, the whole area was planted with tobacco, after the plant residues of the preceding crop had been plowed under. Soil samples were taken in the spring of 1941, in mid-season, and again after the harvest. The soils were studied for their ability to nitrify their own nitrogen, added dried blood, and added ammonium sulfate, respectively. The results of the nitrification studies were compared with the quantity and quality of tobacco produced on the plots in 1940. There was some evidence, in the dried-blood study, that plots giving less active nitrification gave poorer quantity and quality of tobacco.

The study was repeated on a second field in 1941. The set-up was replicated six times, giving 78 plots instead of the 13 studied in 1940. Results of 1941 have not been analyzed sufficiently to permit any statement at the present time.

Comparative Study of Certain Media Employed for Fecal-Flora Studies. (James E. Fuller and Irwin Fried.) Much of the investigational work on fecal bacteriology, in connection with nutritional studies, is based upon determining the ratio of bacteria of the lactobacillus group to those of the coliform group, because a predominance of lactobacilli is considered desirable for intestinal health. It is desirable, also, to differentiate the members of the coliform group present in order to make a useful interpretation of results.

The present study compared certain media commonly employed to enumerate coliform bacteria. Results were as follows: litmus-lactose agar, brom-cresol-purple agar, and lactose agar with Andrade's indicator were not selective for the coliform group of bacteria, and gave no differentiation within the group. Endo's agar and E. M. B. (eosin-methylene blue) agar gave distinctive colonies of the group and good differentiation, but both produced substantially fewer colonies than lactose agar when plates were made with these three media from pure cultures of bacteria of the coliform group. This indicates that both Endo's and E. M. B. media give low counts of coliform bacteria when they are used in fecal-flora studies. Certain combinations of non-coliform bacteria produced reactions on these media that could be confused with those of the coliform group. MacConkey's bile-salt agar inhibited growth of bacteria of the group to a greater extent than did either Endo's or E. M. B. media, and did not give satisfactory differentiation within the group.

The Bacteriology of Chocolate Syrups, Cocoa Powders, and Chocolate Milk. (James E. Fuller and R. W. Swanson, in cooperation with W. S. Mueller of the Department of Dairy Industry.) Bacteria counts showed wide variation in the numbers of bacteria in the different syrups and powders. Most of the bacteria identified were aerobic sporulating bacteria of the *Bacillus subtilis* group. No Gram-negative bacteria of intestinal type were found, which would indicate that the syrups and powders were free from intestinal contamination. Bacteria of this type inoculated into solutions of the syrups and powders survived only a few days.

Growth of bacteria was not as rapid, nor were the counts as large, in milk with syrups or powders added as in the same milk supply without the addition. Thus, it appears that the syrups and powders had some inhibitory effect on bacterial growth. Further studies indicated that the tannins present in the syrups and powders were responsible for the inhibition. Oxalic acid and theobromine, in concentrations found in chocolate or cocoa, had no apparent effect on bacterial growth. Molds and yeasts appeared to be more active than bacteria in causing spoilage of chocolate milk.

Studies of Methods for Determining the Sanitary Quality of Drinking Utensils. (Ralph L. France, W. E. Cassidy, and James E. Fuller.) Work on this project has been completed, with the following results: (1) A swabbing method is the best for recovering bacteria from the lips of a glass. (2) A wet swab is more efficient than a dry or moist swab. (3) The most satisfactory suspending fluid is one having the following composition: 2.5 cc. of 0.04 M $MgSO_4$, 2.5 cc. of 0.01 M $CaCl_2$, 0.5 cc. of 0.001 M $FeCl_3$, and 1.25 cc. of Butterfield's buffered phosphate solution made up to 1000 cc. with distilled water. (4) The most satisfactory plating medium was one with the following substances: Neopeptone, 10 grams; yeast extract, 5 grams; dextrose, 0.5 gram; NaCl, 5 grams; and agar, 15 grams. The reaction of this medium is adjusted to pH 7.5. (5) Inoculation of a swab, or 1 cc. of a 1/10 dilution of washings from the swab, into dextrose broth frequently revealed the presence of mouth streptococci. This test has considerable sanitary significance when used in conjunction with the count. The addition of potassium tellurite to the dextrose broth failed to eliminate interfering organisms.

The Effectiveness of Certain Detergents and Procedures Employed for the Cleansing of Eating and Drinking Utensils. (Ralph L. France.) Field studies have been made of the methods employed in the cleansing and sanitization of eating and drinking utensils in public establishments throughout this area. Bacteriological examinations indicate that these methods are not satisfactory. Work is being continued on this project.

Laboratory Service. (Ralph L. France.) Following is a list of the types and numbers of examinations made during the past year.

Milk (bacteria counts)		895
Ice cream (bacteria counts)		153
Water		124
Eating and drinking utensils		120
Miscellaneous		106
Butter fat:	71	
Solids:	22	
Mastitis:	12	
Burlap:	1	
Total		1,398

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Diseases of Trees in Massachusetts. (M. A. McKenzie and A. Vincent Osmun.)

The Dutch Elm Disease Problem. For several years in the cooperative program for the study of the Dutch elm disease in Massachusetts, intensive effort has been concentrated in Berkshire County as new stations for the causal fungus, *Ceratostomella ulmi* (Schwarz) Buisman, were reported in nearby New York and Connecticut. During recent years, the circulation of numerous false reports that the disease was present in Massachusetts, and even the publication of photographs of trees removed because they were affected by the disease have sometimes confused and alarmed the public. At least a part of the confusion has resulted from the failure to distinguish between the fungus which causes the Dutch elm disease and the principal carrier insect, *Scolytus multistriatus* Marsh., which is a bark beetle infesting certain areas of Massachusetts, notably southern Berkshire County and the region east of Worcester County.

The spread of the disease into Massachusetts was delayed for several years by the eradication of diseased trees in the adjoining states, although early in 1941 it was pointed out[1] that elms in southwestern Massachusetts were in immediate danger from the encroachment of the disease on Berkshire County from New York on the west and Connecticut on the south. However, in September 1941 the first Massachusetts elm in which the presence of the disease could be officially established, was eradicated—a young tree about 20 feet in height growing on private property in the town of Alford. Typical symptoms of foliage wilting and streaking of the woody parts were present. The Scolytus beetle was not found in the tree but has been observed in the town. In the vicinity of the diseased tree and elsewhere throughout Massachusetts, hundreds of other trees showing symptoms macroscopically indistinguishable from those of the Dutch elm disease were checked in field and laboratory studies during the past year, but no additional trees with the disease have been discovered. The work of the organized project of this Station in collecting and studying specimens from suspected trees has been supplemented by other public and private groups and by individuals, including the Massachusetts Department of Agriculture, the United States Department of Agriculture, the Massachusetts Forest and Park Association, town and city tree wardens, employees of other municipal and state departments, arboriculturists, public utilities, and private citizens.

The most constructive procedure in attempting to check the spread of the disease is the removal of all elm material in such a condition as to be attractive to carrier beetles. The quantity of such material present in any location may be related to a number of factors, as in southern Berkshire County where drouth injury and repeated attacks of leaf-chewing insects have seriously weakened many elms in such a manner as to make them suitable for infestation by beetles; and the destruction of this material will doubtless prove of inestimable value in limiting the population of carrier beetles of the Dutch elm disease fungus.

Other Tree Problems. Sixty-nine diseases of thirty-four species of trees, including eleven diseases of elm were identified from more than 500 specimens and inquiries received during the year. The Cephalosporium wilt of elm was reported from 21 municipalities in which no previous cases of the disease were reported,

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[1]McKenzie, Malcolm A. The Dutch elm disease problem in Massachusetts. Published in "Progress Report including Transcriptions of Certain Papers presented at the Eighth Annual Five-Day Short Course for Tree Wardens and Other Workers with Trees," M. S. C., March 28, 1941.

making a total of 173 cities and towns in which the disease has been found in Massachusetts. Also, a fungus, *Verticillium* sp., was isolated from elms in 8 communities in which it was not previously known, and reports show a total of 96 municipalities in which this fungus has been found in woody plants in Massachusetts.

The extended period of dry weather during the summer of 1941 was a serious cause of tree injury, and therefore, additional trouble associated with winter injury may be expected from this source next year, especially in the case of evergreens, which commonly experience winter injury even in years of normal rainfall.

Because of outbreaks of elm pests during the summer of 1940, a circular[2] was prepared this year and distributed to meet the demands for information on the subject.

A disease known as bleeding canker of hardwoods has been reported to be increasing in New England and, at least under certain conditions, the writers have seen cases in which attempted remedies have caused more damage than the fungus. A fungus, *Phytophthora cactorum*, has been described[3] as the cause of the disease, and an organism believed to be the same fungus has been isolated by the writers from elm, maple, beech and oak in Massachusetts, although evidence of serious disease in the host was not always conspicuous. A possible injection treatment employing "Helione Orange" and requiring skilled technicians has been described[4] following preliminary experimental work. Critical evaluation of the results may be possible at some later date; for the present, however, specific recommendations cannot be made.

Current miscellaneous activities of the project included the preparation of parts of the program of the annual Five-day Short Course for Tree Wardens, the compiling of a progress report,[5] the discussion of wood-destroying fungi[6] at the Eastern Pest Control Operators' Conference, and the preparation of newspaper press releases.

The Importance of the Investigation of Tree Diseases in National Defense. In this brief outline of phases of the project which have expanded in relation to national defense, it should be pointed out that it is not possible to distinguish sharply between basic and emergency activities. In fact, none of the following activities are completely new to the project, but increased demands on the part of the public have been classified under three arbitrarily selected groupings among which there is considerable overlapping.

1. Housing projects, new real estate developments, and increased prosperity in general have resulted in increased interest in trees and tree diseases around homes and along streets and highways.

2. As lumbering operations near the point of demand for wood have increased, owing to the necessity for curtailment of transportation costs, supply of labor, shortage of materials, etc., certain types of forest-tree diseases have increased both in the forest and in nearby ornamental trees. The practice of cutting only mature forest trees as a crop maintains a highly desirable, relatively stable biological balance, but only about 5 percent of the nation's forests are operated on this basis in normal times and no hope for an increase in yield-basis operations can be held in the present emergency.

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[2] McKenzie, M. A., and Becker, W. B. Timely spraying protects elms against midsummer defoliation. Amherst, 1941.

[3] Howard, F. L., and Caroselli, N., Phytopathology 30:11. 1940.

[4] Howard, F. L. Science 94:2441:345. October 10, 1941.

[5] Transcriptions of certain papers presented at the eighth annual five-day short course for tree wardens and other workers with trees. Amherst, March 24-29, 1941.

[6] McKenzie, M. A. Wood decay fungi, published in the "Proceedings of the First Annual Eastern Pest Control Operators' Conference," Amherst, January 13, 14, and 15, 1941.

3. Fungus attack on trees does not end when the tree becomes lifeless wood, although proper seasoning and protective treatment will greatly prolong the life of wood in service. Because of the neglect to consider damage from wood decay fungi and related factors, extensive damage to wooden structures has already been observed and additional trouble may be expected.

For the most part, it is common knowledge that tree disease investigations are essential for defense, but the importance of constant vigilance against tree diseas s has been stressed[7] in connection with work on tree problems during 1941. Insidious inroads on public wealth by disease fungi would be rampant if the prosecution of essential disease investigations were relaxed in favor of what, for a thoughtless moment, might appear a greater defense priority need. Disease investigation is primary, vital defense, and in retrospect it is basic to the strong position which this nation holds today.

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modification of Environment. (W. L. Doran.) An Experiment Station bulletin on some of the more immediately useful results of work done under this project has been published[1] and is now in considerable demand.

Work on the vegetative propagation of white pine is being continued. Cuttings rooted in larger percentages and responded more to treatments with root-inducing substances, if they were made with the basal cut at the base of the current year's wood rather than at the base of wood two years old. They rooted better in sand-peat or sand than in sandy soil, and, in one experiment, treated cuttings rooted better in sand than in sand-peat. Best results with January cuttings, 67 percent rooting, were obtained from treatment with indolebutyric acid (200 mg. l., 5 hr.), but there was 58 percent rooting of cuttings treated with naphthaleneacetic acid (100 mg. l., 4hr.), and only 13 percent rooting of the untreated cuttings. Results were less good if cuttings were taken in summer, fall, or earlier in the winter.

Much attention was given to the rooting of cuttings of hemlock and a paper was published[2] on that subject. Cuttings of hemlock, taken in November, rooted best, 100 percent in fourteen weeks, after treatment with indolebutyric acid (100 mg. l., 24 hr.), but naphthaleneacetic acid was also very effective and there were indications that it is sometimes even more effective than indolebutyric acid. Results obtained justify the suggestion that propagators working with late-fall cuttings made of wood of the current year make some use of naphthaleneacetic acid although, with cuttings made with the basal cut at the base of wood two years old, indolebutyric acid in relatively high concentrations was very effective.

A note was published[3] on the rooting of cuttings of umbrella-pine, another species which is usually considered difficult to propagate in this way. They failed to root or to root at all well, treated or not, if taken in September or October; but if taken in January, they rooted 92 percent after treatment with naphthaleneacetic acid (100 mg. l., 2 hr.), decidedly less well if treated with indolebutyric acid. Rooting of December cuttings of *Poncirus trifoliata* was also much more improved by naphthaleneacetic acid than by indolebutyric acid, and lilac cuttings responded better to naphthaleneacetic than to indolebutyric acid. But

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[7]McKenzie, Malcolm A. Municipal shade tree problems in national defense. Published in "Proceedings of the Annual Meeting of the Mass. Tree Wardens' Assn.," February 13, 1941.

[1]Doran, William L., The propagation of some trees and shrubs by cuttings. Mass. Agr. Expt. Sta. Bul. 382, 56 pp. 1941.

[2]Doran, William L. Propagation of hemlock by cuttings. Amer. Nurseryman 74: 6: 18-19. 1941 (Contribution No. 413.)

[3]Doran, William L. Propagation of umbrella-pine by hormone-treated cuttings. Florists Exchange 97:9.9. 1941. (Contribution No. 414.)

indolebutyric acid gave much better results with cuttings of Hinoki cypress than did naphthaleneacetic acid.

Untreated cuttings of *Clematis lanuginosa* var. *candida* and the Clematis variety Ramona rooted at least 80 percent if taken in mid-July, less well if taken a month earlier or later, and their rooting was not markedly improved by treatment with indolebutyric acid.

Cuttings of *Daphne Cneorum*, taken in July, rooted 75 percent without treatment, more than 90 percent after treatment with Hormodin No. 1, and less well than the checks if treated for several hours with solutions of root-inducing substances or with water only.

Up to 24 hours' treatment with water, only, did not affect rooting of hardwood cuttings of *Juniperus communis* var. *stricta*, *Ilex crenata* var. *Helleri*, hemlock, or mock-orange.

Best results with these cuttings of mock-orange (100 percent rooting in five weeks) followed treatment with Hormodin No. 3. Cuttings which were given a short (six hours') treatment with naphthaleneacetic acid rooted more slowly although also to the extent of 100 percent, a decided improvement over results with untreated cuttings for they rooted only 58 percent.

Cuttings of the Rhododendron variety Cunningham's White developed better roots if treatment with a sugar solution (3.0 percent) followed treatment with indolebutyric acid. But treatments with sugar solutions, whether applied before, after, or with root-inducing substances, failed to increase the percentages of rooting of fall cuttings of that plant or of *Gordonia* and *Daphne Cneorum*.

Study of Diseases of Ornamental Herbaceous Plants, Caused by Soil-Infesting Organisms, with Particular Attention to Control Measures. (W. L. Doran.) Formaldehyde properly diluted may, it was found, be applied safely and effectively to soil immediately after seeding without determining the exact rate of application of the solution to each square foot of soil surface. That, however, is most commonly 1 to 1½ pints per square foot. Formaldehyde, so applied to soil immediately after seeding that each square foot received 2 cc. of it, controlled damping-off of Delphinium, Viola, and sweet pea well and equally well whether each square foot received 0.75, 1.25 or 2.0 quarts of the solution.

Formaldehyde, 4.9 cc. (1 teaspoonful) in 1 gallon water or, what is the same thing, 1 tablespoonful in 3 gallons, gave perfect and safe control of damping-off of Nemesia, columbine, Zinnia, China aster, hollyhock, Phlox, Nicotiana, Verbena, Lobelia, and two species of Dianthus when it was applied to soil immediately after seeding without determining exactly what volume of the solution was applied per square foot. This method[1] is noteworthy for its simplicity, since there is no working of chemicals, such as dusts, into soil, no waiting, and, because soil must usually be watered immediately after seeding, not a single additional operation is involved.

When formaldehyde 0.5 teaspoonful in 1 gallon of water was thus applied immediately after seeding, it gave fair but less complete control. If this very dilute solution of formaldehyde was applied more than once, that is immediately after seeding and again once or twice or three times more at intervals of two days, there was injury to Scabiosa by three applications, not by two, and to China aster by four applications, not by three. But results with these repeated applications were not promising, for damping-off was just as well controlled by one application immediately after seeding.

Formaldehyde applied to soil not previously disinfected improved the growth of Calendula, Zinnia, and China aster. But when formaldehyde (2 cc. per square

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[1]Doran, William L. A simple control of damping-off. Florists Exchange 96:21:10. 1941. (Contribution No. 408.)

foot) was applied to soil which had been steamed five days previously, there was some injury, as compared with growth in steamed soil, and there was certainly no improvement in growth as compared with growth in untreated soil. It is concluded that the stimulatory effect of formaldehyde on growth is due principally or wholly to its freeing the plants of the retarding effects of parasitic soil fungi, and it is concluded further that formaldehyde may be dangerous, as regards its effect on some plants, if applied to soil recently steamed.

Spergon (2.7 gm. per square foot) gave fair control of a root-rot of sweet pea seedlings when applied to soil one day before seeding, and there was no injury. But it gave no protection if seeds were sowed thirty days after soil treatment.

Copper oxylate applied to the surface of soil after seeding failed to prevent damping-off of any species.

Semesan (1.1 gm. in 1.2 quarts water per square foot), applied to the soil surface before seeding but not worked into the soil, was not injurious, controlled damping-off fairly well although not completely, and increased by 27 to 100 percent the numbers of seedlings of marigold, Scabiosa, pansy, and sweet pea which lived. Results were less good when the dry Semesan was worked into the soil, for it was then apparently not sufficiently concentrated near or at the soil surface.

Chemical Soil Surface Treatments in Hotbeds for Controlling Damping-off of Early Forcing Vegetables. (W. L. Doran, E. F. Guba, and C. J. Gilgut.) Especial attention was given to the possible use of ammonium hydroxide and ammonium sulfate as soil disinfectants.

Ammonium hydroxide, 12 cc. per square foot of soil surface, controlled damping-off fairly well and without significant injury to seedlings of beet, although seeds were sowed within five days after soil treatment. However, 16 cc. ammonium hydroxide gave better control although, for safety, it was necessary to wait about seven days before seeding.

Ammonium sulfate had little or no fungicidal effect in acid soils, with pH values of 5.0 to 6.0, but it had a decidedly fungicidal action in soil which, as a result of the earlier use of hydrated lime, had a pH value of about 7.0.

When ammonium sulfate and hydrated lime, one part of the former and two parts of the latter by weight, were intimately mixed and this mixture (at the rate of 10 gm. ammonium sulfate per square foot) was worked into moist soil, there was a strong odor of ammonia and damping-off was well controlled. It was, however, necessary on grounds of safety to wait more than five days after soil treatment before seeding.

Hydrated lime alone, applied to soil, usually increased the number of plants which lived and reduced the severity of damping-off, but the disease was not controlled to any such degree as it was by ammonium sulfate and hydrated lime applied together.

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham.) Approximately 30 percent of the greenhouse tomato growing area in the fall cropping season of 1941 was planted to the Bay State tomato, developed for resistance to Cladosporium leaf mold from hybrids of *Lycopersicum pimpinellifolium* × *L. esculentum*. The new tomato was released for trial in 1939. In the fall cropping season of 1940 a new physiologic form of the fungus, to which Bay State is completely susceptible, was noted at Swansea, Bristol County. In 1941, other instances of the complete susceptibility of Bay State to the new form of Cladosporium were observed. Globelle (Ohio) and Vetomold (Ontario) likewise developed for resistance to Cladosporium, and derived from red currant, have shared the same experience. The new physiologic form of the fungus is infectious to *L. pimpinellifolium* (Jusl.) Mill. and *L. hirsutum* Humb. & Bonpl., causing

yellowish infection flecks and ultimately necrosis. On the lower surface of the spots, under moist conditions, the fungus sporulates rather freely, although it is much less virulent on Bay State than the original prevalent form of the fungus. Both *L. pimpinellifolium* and *L. hirsutum* show a high immunity reaction to the original physiologic form of Cladosporium. *L. peruvianum* (L.) Mill. is immune to both physiologic forms but *peruvianum* will not hybridize with *esculentum*.

Causes and Control of Decay of Squash in Storage. (E. F. Guba and C. J. Gilgut, Waltham.) Gourds instead of squash were treated with various disinfectants and chemical coatings after harvest to determine to what extent these treatments influence keeping. The organisms causing decay of squash similarly attack gourds and the results from such treatments are generally applicable.

The merit of spraying gourds with Bordeaux mixture 4-4-50 and 1 pound calcium arsenate during the growing season was investigated, although it is recognized that the spraying of squash is difficult. The results indicate that fungicidal field treatments result in less decay after harvest and that the progress of decay is further inhibited by coatings of shellac. The value of disinfection between harvest and storage is not clearly shown. A dry ventilated storage following protection in the field with Bordeaux mixture and calcium arsenate was definitely advantageous in the control of decay.

It is apparent, particularly as the result of this season's work with gourds, that considerable infection responsible for decay in storage may take place in the field, without being evident at harvest.

Gardenia Stem Canker. (C. J. Gilgut, Waltham.) It was determined from a histological study of gardenia cankers that the hyphae of the infecting fungus, *Phomopsis gardeniae* Hans. & Scott, are confined to the discolored bark and wood of the cankered section of the stem. Cuttings taken from diseased plants and from healthy plants did not become infected when propagated side by side in clean sand, nor did plants from these cuttings become cankered when grown in greenhouse benches.

Disease Resistance and Heredity of Carnations. (E. F. Guba cooperating with H. E. White, Waltham.) Approximately 75 varieties of carnations have been studied for their reaction to fungus wilt diseases. Also, growers have indicated the performance of a long list of varieties in relation to these diseases under their respective growing conditions. In a compilation of these reports and tests, it is apparent that certain carnation varieties have rather consistently maintained healthy growth. The wilt diseases under consideration in this study are caused by *Alternaria dianthi* (blight), *Rhizoctonia solani* (stem rot), *Fusarium dianthi* (branch rot) and *F. avenaceum* and *F. culmorum* (stem and root rot), and are not equally prevalent. Frequently, only one of these diseases may be troublesome year after year in the same establishment. Twenty-six varieties showing the greatest promise as sources of disease resistance under natural conditions have been selected for further study. The reactions of these varieties to each wilt disease in so far as available will be more carefully scrutinized under more favorable conditions for disease and artificial methods of inoculation before hybridization studies are undertaken. The results of this program should determine the nature, justification, and direction of further effort in the development of desirable disease-resistant types of carnations.

Miscellaneous Tests and Experiments. (E. F. Guba and C. J. Gilgut, Waltham.)

1. *Apple Scab Control.* Ground and chemically prepared sulfurs of a maximum particle size of 50 and 3 microns respectively were compared on an equivalent sulfur basis, and in combination with lead arsenate, and lead arsenate and

lime, for loss of sulfur by weathering, for scab control, and for chemical injury. There were no apples to harvest from the untreated row because of a complete June drop caused by the plum curculio. In this row 20.3 percent of the leaves were scabby and only a small amount of this was primary infection. In the sprayed rows, irrespective of whether the sulfur was coarse or fine, there was no scab.

The results confirm the work of previous years to the effect that sulfur particle size and concentration of sulfur are not as important in scab control as good spraying. Chemical determinations of the residues after spraying revealed that the loss of sulfur by weathering was greater with Magnetic Spray Wettable Sulfur than with dry wettable Flotation Sulfur, early in the season. In both cases more sulfur was retained on the foliage when the combination of sulfur and lead arsenate was used without lime. Fish oil added to Flotation Sulfur, lead arsenate, and lime increased the deposit and retention of sulfur. No improvement was shown by substituting Soya flour for fish oil in the first and second cover sprays. No consistent benefit in the deposit and retention of sulfur otherwise could be shown with the types of sulfur used by the addition of Soya flour.

2. *Copper Dusts for Cucumber and Muskmelon.* Fifteen proprietary and two home-mixed copper dusts containing different sources of metallic copper were tested on cucumber and muskmelon planted in rows of 5 hills of 5 plants per hill. The copper content of the dusts varied from 4.75 to 7 percent. Some contained an insecticide (either 20 percent cryolite, 0.75 percent rotenone, or 5.75 to 10 percent calcium arsenate) added for the control of striped cucumber beetles. The dry summer was unfavorable for the usual foliage diseases, but bacterial wilt and mosaic were present on cucumber.

A proprietary dust containing 5 percent metallic copper and 20 percent cryolite was injurious to both muskmelon and cucumber. On the basis of plant condition and yield, the five best treatments on cucumber were:

6 percent Cu in tri-basic copper sulfate and 0.75 percent rotenone
6 percent Cu in tri-basic copper sulfate
5 percent Cu in copper oxychloride sulfate and 1 percent rotenone
7 percent Cu in tri-basic copper sulfate and 0.75 percent rotenone
5.16 percent Cu in red copper oxide and 0.75 percent rotenone

The best treatments on muskmelon were:

6.5 percent Cu in tri-basic copper sulfate and 0.75 percent rotenone
6.5 percent Cu in tri-basic copper sulfate and 10 percent calcium arsenate
6 percent Cu in tri-basic copper sulfate and 0.75 percent rotenone
5.16 percent Cu in red copper oxide and 0.75 percent rotenone
5 percent Cu in copper oxychloride sulfate and 7.5 percent calcium arsenate
4 percent Cu in copper hydroxide and 7 percent calcium arsenate

The differences between the best copper treatment combinations and a 0.75 percent rotenone dust on muskmelon were not significant in 1941.

3. *Mercury Compounds for Control of Club Root of Crucifers.* In a preliminary exploratory experiment calomel and mercuric bichloride in varying amounts were used for the control of club root of cabbage and cauliflower. Applications were made to seed flats and in the field at different times and by various methods. Because of uneven infestation in the experimental block, the results were indefinite and no conclusions can be made.

4. *Vegetable Seed Treatments for Damping-off Control.* For the second successive year cooperative tests of vegetable seed treatments were conducted under the auspices of the committee for coordinated seed treatment research of the American Phytopathological Society. Weighed amounts of treated seed (treat-

ment based on weight of seed) were furnished to the cooperators by the committee. Five replications of 100 seeds for each treatment and no treatment were counted and planted in randomized blocks.

With cucumber, there was no significant difference between treatment with 0.25 percent red copper oxide, 0.75 percent Semesan, and no treatment. Treatments with 2 percent red copper oxide, 2 percent zinc oxide, and 0.2 percent Semesan showed no significant differences with celery; but with lettuce 2 percent red copper oxide and 2 percent zinc oxide were significantly better, in the order given, than no treatment. With sweet corn, 2 percent red copper oxide, 2 percent zinc oxide, and 0.2 percent Semesan Jr. were no better than no treatment. Cabbage was distinctly benefited by 2 percent zinc oxide and 0.2 percent Semesan. From seed treated with hot water and subsequently with chemical dusts, the stands were reduced, yet they were better than stands from seed treated only with hot water.

The value of a number of dry chemical powders in preventing pre-emergence damping-off and seed decay of lima beans was determined. Spergon-treated seed produced a larger number of seedlings and consequently a greater yield of lima beans than seed receiving any other treatment or no treatment. The second best treatment was red copper oxide, which held a slight advantage in number of seedlings and yield over zinc oxide. Semesan was distinctly injurious to the seedlings, the injury persisted throughout the growing season, and the yield was materially reduced. Although more seedlings grew from seed treated with Semesan than from untreated seed, the total yield from untreated seed was nearly twice that from Semesan-treated seed.

Effect of Vitamin B_1 at Different Soil Temperatures on Gardenia Chlorosis. (L. H. Jones.) Gardenia plants became chlorotic at soil temperatures of 55°, 60°, and 65° F. The soil was treated weekly with a solution of thiamin chloride (vitamin B_1), one part in ten million, used at a temperature equal to the soil temperature. The plants were replicated in sufficient containers so that the thiamin chloride could be applied before, at the observable period when, and after chlorosis appeared. There was no noticeable evidence that thiamin chloride at this concentration could prevent chlorosis induced by low soil temperatures or cure a gardenia plant so affected.

In a later test with chlorotic plants, soil treatment with 100 times the above concentration (1 part in 100,000) did act as a mild remedial measure. New leaves at the unfolding stage were dark green in color, old leaves had the yellowing between the veins supplanted with a healthy green color, and basal shoots developed with dark green foliage. Since this effect took place at about the time of the vernal equinox, it appears that this concentration of thiamin chloride hastened what would have occurred normally a short time later. Since the temperature of the solution when applied corresponded to the soil temperature, the results must be ascribed to the use of vitamin B_1.

The Effect of Soil Temperature on Growth. (L. H. Jones and J. W. Hall.) Corn, tomato, and rose were used as indicator plants. When soil temperatures were altered to 55°, 60°, 70°, 80°, and 90° F., plants which were established in the soil at 75° showed marked effects of temperature on development over a period of 78 days. There was poor growth and no flowering of corn, tomato, and rose plants at soil temperatures of 55° and 60°, but at 70°, 80°, and 90°, the plants grew vigorously and flowered. Corn and rose plants did best at 90°, while the tomato, John Baer, apparently was at its optimum environment at a soil temperature of 80°. Internode length in corn increased up to a soil temperature of 70°, while the internodes of the tomato plant were longest at 80°. The air tem-

perature was maintained at about 80° F. The resulting differences in vegetative and reproductive development are, therefore, attributable directly to soil temperatures.

The Effect of Root Media on Root Structure. (L. H. Jones and B. Eames.) Soybean and corn plants grew equally well in either sand or solution culture and could be shifted from one medium to the other without any drastic effect on the root system. Roots in sand cultures were thicker and kinked as compared with the slender, smooth roots grown in solution. A study of the root structure before and after transfer from one type of medium to the other did not disclose any particular modification of root structure other than an increase in the amount of cortex in roots developed in the sand medium.

Geranium cuttings, rooted in sand and transferred to a solution medium, developed new roots at the callus above the level of the solution, the original roots dying in the solution. On the other hand, chrysanthemum cuttings were able to continue growth without the necessity of producing a new set of roots, the original roots being able to function when transferred from sand to a solution.

DEPARTMENT OF CHEMISTRY

W. S. Ritchie in Charge

Analytical Service. (The Department.) Many of the analytical services, formerly performed by the department, have been taken over by the Control Laboratories.

The analysis of various blueberry bushes, particularly for iron and manganese, from an "elemental" fertilizer experiment have been completed for the Department of Pomology.

Samples of a lubricating oil and fungicides have also been examined.

Testing Analytical Methods. (E. B. Holland.) The work of several years on a method for the determination of zinc in foodstuffs has been completed, and the procedures appeared as a part of bulletin 379 of this Station.

A study of the method for the determination of fluorine in insecticides has been started, and will receive additional attention during the coming year.

The Iron, Copper, Zinc, and Iodine Content of Fruits and Vegetables. (E. B. Holland, C. P. Jones, and W. S. Ritchie.) During the past several years a large number of foodstuffs for both man and beast have been collected, and analyzed for the above elements, as well as for approximate analyses. The results have been classified and tabulated, and published as bulletin 379 of this Station.

Lignin and Its Relation to the Absorption of Minerals by Plants. (Emmett Bennett.) This project is being continued in much the same way as outlined previously in other reports. Derivatives of lignin have been prepared. Attempts are being made to fractionate these compounds and correlate such fractions with certain properties of lignin. Limited data do not warrant conclusion at this time.

Hemicelluloses. A preliminary attempt is being made to obtain and characterize the hemicellulose fractions of several different species of grass, with the hope of being able to correlate such differences as may exist with differences in species composition. Extractions have been completed and some fractions have been isolated, but as yet no data have been obtained regarding species differences.

Chemical Investigation of the Onion. (Emmett Bennett). One paper on the effect of storage of the Ebenezer onion has been published in Volume 39 of the Proceedings of the American Society for Horticultural Science.

A preliminary examination of the soluble carbohydrates indicates that the reducing sugars are probably glucose and fructose. This indication is substantiated by the formation of osazones characteristic of these sugars and by the products of oxidation produced by iodine. According to the latter test the non-reducing sugars are composed of approximately one third aldose sugar and two thirds ketose sugar. This general distribution is to some extent substantiated by the polariscopic behavior of solutions of the mixed sugar fractions. Prior to inversion the optical rotation is usually slightly negative. After hydrolysis the optical activity is decidedly more negative. Such response is usually indicative of an inulide fraction. Further identification of these carbohydrate groups by means of definite derivatives has not been successful. Analytical methods for other compounds concerned with the several phases of the project have also been evaluated.

Chemical Changes in the Cooking Quality of Vegetables. (Monroe E. Freeman and W. S. Ritchie.) A new technique for estimating the texture of cooked potato tissue was reported in the annual report for 1940. This technique has been developed into a quantitative method based on the observation that mealy tissue becomes porous on drying while waxy or soggy tissue becomes non-porous. The pore volume of dried slices of tissue can be measured quantitatively by weighing the samples under toluene when the pores are filled with air and when filled with toluene. From these data the weight percent of toluene filling the pores can be calculated and used as an index of texture. The samples were thoroughly dried (in vacuo over P_2O_5), weighed in air and then under toluene. The weight of the sample under toluene with all the pores filled with toluene was calculated from the predetermined density of the potato dry matter and the density of the toluene. Toluene indices ranged from 0.15 to values as high as 6.30 percent and were easily reproduced within experimental error of ± 0.05 to ± 0.10 percent.

The method was carefully checked by determining the specific gravity of a large number of tubers, baking them, estimating the mealiness by personal judgment, and measuring the toluene index. In all cases there was very satisfactory agreement among these methods for estimating texture. Specific gravity and judging method for texture estimation are rapid but distinguish only four or five grades of texture. Toluene index is a longer and more technical method but it has the distinction of offering a quantitative measure of potato texture or cooking quality and therefore offers a great advantage to research workers in this field.

A storage experiment on potatoes is now under way to demonstrate the applicability of this research tool. Samples of tubers are being stored at 35° and 50° F., and in commercial storage. Samples will be withdrawn at intervals and the texture measured by the three methods as above.

Physico-Chemical Properties of Starches. (Monroe E. Freeman.) Very little accurate information is available regarding the chemical and physical properties of the different starches that control the properties of manufactured dextrins, because the industry is operated largely as an art or a craft. The introduction of precise scientific control can undoubtedly be facilitated by the accumulation of data on (a) the chemical and physical properties of the starches, (b) the conversion process itself, and (c) the chemical and physical properties of the dextrins.

Experimental apparatus has been designed, constructed, and tested that intimately mixes a fine spray of acid with a dust cloud of starch. Moisture con-

tent, concentration, and rate of flow of acid and starch can be regulated. An electrometric titration method for measuring small concentrations of acid in starch has been satisfactorily worked out. Apparatus for heating the acidified starch under thermostatic control, uniform agitation, and a controlled atmosphere of air, carbon dioxide, or nitrogen has been designed and constructed.

There exists a real need for an adequate description or definition of the different grades and types of modified starches. This problem has been approached by studies on the physical and chemical properties of commercial dextrins. Analyses for moisture, reducing sugar, copper-reducing power, alkali lability, solubility, iodine color, ash, bound water are in progress on a series of commercial samples and their fractions. Characterization of dextrins by the ratios of significant fractions is also under investigation. Several dextrins have been fractionated by alcohol and the dextrin acetates have been fractionated by organic solvents. Characterization of the dextrin fractions is being carried out by end group assays and viscosity–molecular weight determinations.

Studies of the physical and chemical properties of the starches have begun with an examination of the phosphorus content of several starches. An electrodialysis technique was developed for quantitatively measuring the inorganic and the organically bound phosphorus in natural starches and in phosphorylated starches. Since size of starch grains is believed to be a factor influencing the character of the manufactured dextrins, a grain size classifier for separating large-grain and small-grain fractions has been designed. Since water relations play an important role in the conversion of starch, studies have been continued on the bound water and free water relationships.

Several methods for determining the bound and free water ratio in starch have shown that potato starch suspensions contain about .3 gram of bound water for each gram of dry starch. Canadian and Russian workers have reported anomalous heat capacities for suspension of hydrophyllic colloids and these data were interpreted as indicating a lower specific heat for bound water thus affording a new method for measuring the bound water. Similar data were collected in this laboratory for starch water suspensions. Careful analysis of the data, however, shows definitely that the above interpretation is erroneous. The anomalous behavior of the starch water suspensions can be accurately described by linear equations embracing a discontinuity at the point where all the water in the starch suspension is bound. An explanation of this phenomenon is awaiting verification by experiments on other systems of hydrophyllic colloids.

Investigations on the Nutritive Value of Fishery Products as Human and Animal Food. (Monroe E. Freeman and W. S. Ritchie.) The Progressive Decomposition of Fish Muscle. Studies on the first stages of protein decomposition in fish muscle (Annual Report—1940) were followed by investigation of more extensively decomposed muscle tissue. About twenty-five different fractions were isolated as picrate derivatives from one large sample of haddock muscle. None of these compounds nor their derivatives exhibited clearly defined melting points. Consequently their identification depends on ultimate analyses for carbon, hydrogen, and nitrogen; and determination of molecular weights. Since many of these picrates are violently explosive, special techniques have been devised to facilitate semi-micro combustion and Dumas analyses.

The Influence of Base Exchange Capacity and of Exchangeable Ions in Massachusetts Soils on the Availability of Potassium. (Dale H. Sieling.) As a forerunner to the actual investigation of soils collected for this study it seemed advisable to use the soils most readily obtainable in large quantities for physiological

tests with plants. This was done by varying the base exchange capacity and the calcium–hydrogen ratio of the soil artificially over the range of these values observed for the other soils. It was thought that this method of approach would establish certain facts that might then be confirmed by using the naturally occurring soils for similar tests.

The basic soil used in these tests was classified as Agawam fine sandy loam. It had a pH of 5.7, an exchange capacity of 7.13 M. E.* per 100 grams and an exchangeable calcium content of 2.91 M. E. per 100 grams. The material added to the soil to vary the base exchange capacity was electrodialyzed bentonite, an inorganic colloidal material having a base exchange capacity of 73.5 M. E. per 100 grams. The calcium–hydrogen ratios of both the soil and the electrodialyzed bentonite were adjusted to the desired values by liming with calcium hydroxide. The base exchange capacity at any desired calcium–hydrogen ratio was varied between the value for the soil and that for the bentonite by mixing the two constituents.

Pot cultures were prepared by this method which varied in reaction from pH 5.7 to 7.15 and in base exchange capacity from 7.13 to 13.16 M. E. per 100 grams of soil. Phosphorus, potassium, magnesium, and nitrogen were kept constant in the various cultures by adding weighed quantities of the salts of these materials. Duplicate series of pot cultures, with and without added boron, were prepared to check the influence of calcium level and pH on the occurrence of boron deficiency—a condition often associated with "over-liming."

Four tobacco seedlings (Kightlinger's No. 211), five weeks old, were transplanted in each culture. The cultures were watered daily with distilled water and after two weeks three of the four plants of each culture were removed. The remaining plants were grown for a total of eight weeks and then harvested by cutting each plant off at the soil surface. The plants were dried at 60° C. and the dry weight was recorded. The dried plants have been stored and will be analyzed for potassium to see if there was any appreciable difference in the uptake of that element.

During the growing season nitrogen deficiency developed in the plants of some of the cultures even though this element was added from time to time. It seems quite likely that insufficient nitrogen was supplied in the cultures. From the appearance of the plants there was not a lack of boron in any of the cultures or at least there was enough to prevent deficiency symptoms from occurring regardless of the reaction of the soil or its calcium level. The dry weights of the plants were not greatly different although there was a tendency for the dry weight to decrease at any pH as the exchange capacity and the calcium level increased. This observation was most pronounced at pH 5.7. Since nitrogen deficiency was observed in most of the cultures it seems logical to believe that variations in growth or potassium utilization due to calcium–hydrogen ratio or base exchange capacity would be minimized.

These same cultures will be used to grow a second crop during the summer of 1942, with the hope of gaining more information about the influence of these various factors on plant growth and the utilization of potassium by plants.

The Relationship of Base Exchange Capacity, Exchangeable Hydrogen, and Soil Reaction to the Lime Requirement of Massachusetts Soils. (Dale H. Sieling.) Samples of the various soils obtained for determining the relationship between lime requirement and the exchange capacity and exchangeable hydrogen were limed with increasing quantities of calcium carbonate. Conditions of liming were established to simulate the actual conditions in the field by placing the soils on top of a layer of sea sand in lacquered metal cans perforated at the bottom.

*M. E. = milli-equivalent.

This system allowed for drainage of the soils and also the actual determination of the pH of the soils in place. The soils were limed at a rate of from 125 to 1000 pounds of calcium carbonate per acre-inch, based on previously determined volume weights of the soils as they were found in the field.

The reactions of the soils of each series, variously limed, were determined at regular intervals. The soils were wetted with distilled water and allowed to stand overnight to permit drainage of the excess water and the removal of nitrates that may have accumulated as a result of bacterial action. The pH values were determined in duplicate samples of soil dampened with water and with saturated potassium chloride. The pH values obtained with the use of potassium chloride were considerably lower than those obtained with water. The amount of lowering of the pH value due to the presence of the salt showed a relationship to the exchangeable hydrogen content of the soil. The indications are that, in general, soils of higher exchange capacity require greater quantities of lime for neutralization than do soils of low exchange capacity at the same initial reaction. The data obtained have not been sufficient to establish any quantitative relationship between the exchange capacity, the initial reaction, and the lime requirement.

Similar experiments set up under field conditions in the localities from which the soils were obtained gave results parallel to those found in the laboratory, except with the two soils which had received a large quantity of commercial fertilizer for growing onions. It is believed that fertilizer produced a lowering effect on the reaction similar to that observed when potassium chloride was added to the soil under laboratory conditions.

Soils having higher base exchange capacities than those obtained originally for these tests have been secured and will be tested in a similar manner.

The Effect of Orchard Mulches on the Plant Nutrient Elements in the Soil. (Dale H. Sieling and J. K. Shaw.) The objectives of this experiment are to investigate the influence of mulching on the accumulation and movement of nutrient cations and of phosphates in an orchard soil and to study the effects of mulching on the trees.

Six mature McIntosh apple trees which had been fertilized with complete fertilizer for the past ten years and had been cultivated during that time were selected for this study. Three separate plots consisting of two trees each were treated as follows: Plot 1 received an application of 290 pounds of hay per 1600 square feet and will be mulched from time to time with hay of known mineral composition; Plot 2 received Fiberglass wool of 2-3 inches in thickness; and Plot 3 was left fallow and will be cultivated in the usual manner.

Soil samples were taken at two systematically located positions under each tree before mulching was started. At each sampling location four samples were taken at specified depths so that any movement of mineral nutrients resulting from mulching might be detected when further samples are obtained and analyzed.

The samples of soil were stored in sealed glass jars to prevent loss of moisture and the subsequent fixing of potassium and other mineral nutrients. After the moisture in the soil had been determined, samples were extracted by the neutral ammonium acetate method and the extracts were analyzed for the exchangeable ions: hydrogen, calcium, magnesium, and potassium.

From the analysis it has been observed that the base saturation of this soil was very low and conversely the hydrogen saturation was very high. In one surface sample the base saturation was as low as 5.2 percent. The amount of exchangeable potassium in the surface soils ranged from 100 to 200 pounds of potassium per acre for a 6-inch depth. This amount of potassium is usually considered adequate for good crop production but may become a limiting factor as the other elements are increased since the subsurface soils contain a much smaller amount of this element. The exchangeable calcium was exceptionally

low, especially in the subsoils, where only 28 pounds of calcium were found per acre for each 6-inch depth. The calcium level of the surface soils was higher but in no case exceeded 270 pounds per acre for a 6-inch depth.

The exchangeable magnesium ranged from an amount too small to be measured by the method employed to 43.2 pounds per 6-inch layer of an acre. It might be suspected that magnesium deficiency would occur on these trees under certain growing conditions, since these amounts of magnesium are considered inadequate for normal plant production.

Total and available phosphorus will be determined on the soils previously collected and on those obtained in the future, to see if the addition of organic matter has any mobilizing effect on phosphate. Mineral analyses will also be made of the samples collected in the future to determine the influence of mulch on the amount or mobilization of the various mineral nutrient elements.

The Fixation of Arsenic in Soils and the Influence of Arsenic Compounds on the Liberation of Fixed Phosphates. (Dale H. Sieling.) Anion fixation in soils is very important from the standpoint of the decrease in availability of phosphates added as fertilizers to the soil. This study was undertaken to see whether arsenates were fixed in a similar manner to phosphates and would replace fixed phosphates. If the arsenic from spray residues were fixed, it would show to some extent the reason why such quantities of arsenic do not depress the growth of plants in soils while growth of plants is inhibited in cultural solutions containing the same amount of arsenic. The fundamentals involved in anion exchange or fixation by the soil can best be studied by using pure clay fractions found naturally in soils.

Purified Kaolinite and Halloysite, clay minerals commonly found in soils, have been investigated for their property to adsorb arsenates. It has been found that these clay minerals, as they ordinarily exist in large deposits, do not fix appreciable quantities of either phosphates or arsenates at pH 3.0. Grinding of these minerals in a ball mill for a period of 20 days reduced the particle size to more nearly that of soil clay particles and increased the activity of both minerals in fixing arsenates and phosphates.

Five-gram samples of these minerals were shaken continuously for 24 to 72 hours in stoppered bottles containing measured quantities of a normal solution of either phosphoric or arsenic acid adjusted to pH 3.0 with sodium hydroxide. The fixation was measured by determining the decrease in concentration of the ion in the solution after removal of the clay by centrifuging. Fixation was not instantaneous but followed a pattern somewhat similar to that reported for phosphate by other workers and confirmed in these tests. Arsenate was fixed in quantities practically equivalent to phosphate by the Kaolinite clay but in somewhat smaller amounts than phosphate by the Halloysite; however both arsenate and phosphate fixation by pulverized Halloysite exceeded the amounts of these ions fixed by Kaolinite.

Further study is being conducted to establish the relative ability of each of these two negative ions to replace the other when it has been fixed by these clays.

CONTROL SERVICE

Philip H. Smith in Charge

The Fertilizer, Feed, and Seed Control Laws and the Dairy Law are all administered as one service. In addition, a large amount of work is done not only for other departments of the institution, but also for other State institutions and for citizens as well.

Fertilizer Inspection. Records for the year show that 118 firms have registered 501 brands of mixed fertilizers and fertilizing materials and 45 brands of agricultural lime and gypsum. The gross receipts from the registration of the fertilizer and lime products and from fertilizer tonnage fees were $14,711.41.

For inspection purposes 1,746 samples, representing 490 brands and 8,433 tons of materials, were drawn from stock found in the possession of 393 agents or owners located in 144 towns and cities of the State.

The following summary shows the character of these substances, as well as statistics with reference to their inspection.

	Brands Registered	Brands Collected	Samples Drawn
Mixed fertilizers	330	299	1,021
Ground bone, tankage and fish	35	35	190
Nitrogen products, mineral and organic	48	41	151
Phosphoric acid products	26	23	112
Potash products	24	23	85
Dried pulverized natural manures	23	22	73
Nitrate of potash	3	3	9
Peat products	3	2	2
Wood and cotton hull ashes	6	4	6
Emjeo (30% magnesium oxide)	1	—	—
Miscellaneous	2	1	5
Lime products	45	37	92
Totals	546	490	1,746

Feed Inspection. During the fiscal year 1,331 samples of feeding stuffs were officially collected and examined in the control laboratories. The gross receipts from the registration of feeding stuffs in 1941 were $27,220, derived from 1,361 brands at $20 each.

Dairy Law. During the year ending December 1, 1941, 6,738 pieces of Babcock glassware were tested; 107 certificates of proficiency were awarded; and 239 creameries, milk depots, and milk inspectors' laboratories were visited in order to check methods and to pass upon equipment in use. As a result of this inspection, four machines were condemned. These will be either replaced or put into condition to operate satisfactorily.

Miscellaneous Analytical Work. (Fertilizer and Feed Laboratory.) In addition to the work required by the several regulatory activities under its administration, Control Service is interested in collaborative work with other departments of the Experiment Station and College; the examination of samples of feeds, fertilizers, and other agricultural products submitted by citizens of the State; the testing of feeds and fertilizer bought by State institutions; and investigational work on new methods of chemical analysis for the Association of Official Agricultural Chemists.

In order to indicate the wide scope of the work, the following statistical data are appended:—

Fruit spray residue	16
Feeds, from farmers and dealers	57
Feeds, from State institutions	892
Feeds and forage crops, Experiment Station	182
Fertilizer mixtures	12
Ice Cream	130

Insecticides and fungicides	2
Limestone (AAA distribution)	12
Milk	362
Ore	8
Peat	1
Poultry feces (In connection with experiments)	9
Poultry grits	6
Referee and check samples, fertilizer and feed	11
Specimens for mineral poison	3
Superphosphate (AAA administration)	11
Water	4
Miscellaneous	19

Seed Control. From December 1, 1940, to December 1, 1941, the Seed Laboratory received and worked 3024 samples of seed, of which 942 were collected by the State Commissioner of Agriculture and 2082 were sent in by seedsmen, farmers, and various State institutions. In addition, 209 samples of flower seeds, for field tests only, were received from the State Commissioner of Agriculture.

Classification of these samples, with the total number of laboratory tests involved, is shown in the following summary. It will be noted that 3998 tests were required for the 3024 samples; 672 for purity, and 3326 for germination.

Number of Samples		Number of Tests Purity	Germination
544	Field Crops for Purity and Germination	544	544
2	Field Crops for Purity Only	2	—
235	Field Crops for Germination Only	—	235
81	Lawn and Other Types of Mixtures for Purity, Germinations involving 393 ingredients	81	393
35	Lawn Mixtures for Purity Only	35	—
7	Lawn Mixtures for Germination Only, Germinations involving 36 ingredients	—	36
1926	Vegetables for Germination Only	—	1926
46	Herbs for Germination Only	—	46
16	Flower Seeds for Germination Only	—	16
2	Flower Seeds for Purity Only	2	—
8	Flower Seeds for Purity and Germination	8	8
13	Tree Seeds for Germination Only	—	13
109	Tobacco Seeds for Germination Only	—	109
3024	Totals	672	3326

Field tests to determine trueness to type were conducted in cooperation with the Departments of Olericulture, Floriculture, and Agronomy, which tested 220 samples of vegetable seeds, 209 samples of flower seeds, and 30 samples of oats, respectively.

The Seed Laboratory cleaned 90 lots of tobacco seed for Connecticut Valley farmers. The gross weight of the tobacco seed was 131.28 pounds and the net weight for the cleaned seed was 102.17 pounds.

Corn, oats, barley, and wheat, (162 samples), purchased by various State institutions, were examined for conformity to grade purchased; and 98 samples of ground cattle and poultry feed, collected by inspectors or sent in by dealers and farmers, were examined microscopically.

THE CRANBERRY STATION
East Wareham, Massachusetts
H. J. Franklin in Charge

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Hill Fireworm (*Tlascala finitella* (Walker)). One and a half acres of the Summit Cranberry Company's bog at Greene, R. I., replanted in the spring of 1941, were seriously infested in the hills by this insect in mid-July. Vines planted there in 1940 were also attacked but less severely and more along the runners lying on the sand than in the hills. These infestations were curbed completely by spraying and dusting heavily with rotenone materials.

About 50 acres of heavy vines of the Burrage bog at South Hanson, Mass., were found to be infested throughout by this insect from July 12 to August 12, 1941. The worms were everywhere rather plentiful there in the thicker clusters of vines during the latter half of July, being mostly in their tubes of frass and silk well down among the vines but considerably above the bog floor. They did considerable, but not severe, damage by devouring under leaves and blossoms. The superintendent of the bog said it had been similarly attacked by this pest in 1940.

Many of the worms were about full grown on July 19, 1941. A few were still present in their tubes among the vines of the Burrage bog on August 12. The largest were about thirteen sixteenths of an inch long, with the head black, the cervical shield black with a much-broken pale yellow stripe along its front margin, the body dark brown, striped lengthwise on the back and sides, except toward the hind end, with about eight narrow and broken pale yellow stripes, these being most conspicuous toward the front end. The first moths to appear in confinement emerged August 8 and more came out from August 10 to 20. Many live pupae remained on November 18.

Some of these worms were found in their tubes among the foliage of cultivated swamp blueberry bushes at the station.

Cranberry Root Grub (*Amphicoma vulpina*). Some of these grubs were sent to the Japanese and Asiatic beetle laboratory at Moorestown, New Jersey, in January 1941, to have their susceptibility to the milky disease organism determined. Mr. C. H. Hadley, in charge of the laboratory, reported later as follows:

> With further reference to my letter of January 10th regarding tests to determine the susceptibility of the cranberry root grub, *Amphicoma vulpina*, to the milky disease organism, we have completed the preliminary tests with the material which you sent me in January. Negative results were obtained both by injection tests and feeding tests with the type A milky disease organism, *Bacillus popilliae*. No evidence of milky disease development was observed either by macroscopic examination or upon microscopic examination of the blood of the injected individuals. Neither was there any indication of development of the organism in larvae which had been given opportunity to feed in infected soil. We must, therefore, conclude that this species of larva is not susceptible to milky disease infection.

Late in the spring, one of the cranberry growers started further tests of paradichlorobenzene as a control for this pest, applying the chemical with a fertilizer spreader at the rate of 1200 pounds an acre and covering it at once with about an inch of sand. His plots were examined late in August and nearly all the grubs were found to have been killed, even where flooding for frost protection and for insect control had been done soon after the treatment was applied. This treatment probably will be useful in special situations, as on bogs that cannot be treated with cyanide because they drain into public water supplies, or perhaps on bogs with a surface soil too dense to take in the cyanide solution readily.

Quite a number of bogs were reflowed from mid-May to mid-July, 1941, to check severe infestations of the root grub. This treatment was generally fairly successful, as it usually has been heretofore, but it was found that in several cases some grubs survived.

Cranberry Fruit Worm (*Mineola vaccinii*). Arsenate of lead, 8 pounds in 100 gallons of water with a casein spreader, applied at the rate of 400 gallons per acre at the times when derris and cryolite are most effective, controlled this insect very well on experimental plots, but less completely than derris or cryolite. Xanthone, both in a spray and in a dust, failed to affect it appreciably.

Gypsy Moth (*Porthetria dispar*). Cryolite, 14 pounds in 100 gallons of water, 400 gallons an acre, failed to cause much reduction in the number of maturing caterpillars on a bog, as did also dusting with 100 pounds of natural cryolite per acre.

Cranberry Girdler (*Crambus hortuellus*). Fifty pounds of 4 percent rotenone derris dust (without activator) to an acre killed nearly all the moths of this pest on a treated area, but was not quite so effective as pyrethrum.

Black-headed Fireworm (*Rhopobota*). An interesting development was the use of a mixture of cryolite and impregnated pyrethrum dust. Treatments with this mixture cost no more than those with clear pyrethrum dust and seemed to have greater value, especially with the first brood. The cryolite provides a considerable control after the pyrethrum ceases to act and so takes care of most of the young worms as the eggs continue to hatch.

Prevalence of Cranberry Pests. The relative general abundance of insect pests on Massachusetts bogs in the 1941 season was as follows:

1. Gypsy moth more abundant and destructive in Plymouth County than for many years, but much reduced on the middle and outer Cape, not giving much trouble there.
2. Blunt-nosed leafhopper (*Ophiola*) reduced as in recent years, because of general treatment.
3. Cranberry fruit worm only moderately troublesome and through working early; much less prevalent than in 1940, less eggs being laid by the moths, and the eggs being attacked by the *Trichogramma* parasite more severely and generally than usual.
4. Black-headed fireworm less abundant than usual and less than in 1940.
5. Firebeetle (*Cryptocephalus*) generally very scarce, but abundant on 10 acres of a bog in Norton.
6. Spanworms about the same as in 1940.
7. False armyworm (*Xylena*) even more prevalent than in 1940; more troublesome than for many years. Blossom worm even less prevalent than in 1940.
8. Cranberry girdler more harmful than in 1940.
9. Cranberry weevil about as in 1940.
10. Cranberry spittle insect (*Clastoptera*) and tipworm (*Dasyneura*) rather more troublesome than in 1940.
11. Spotted fireworms (*Cacoecia*) very few.

Control of Cranberry Bog Weeds. (Chester E. Cross.) Paradichlorobenzene, naphthalene, ferric sulfate, ferrous sulfate, copper sulfate, borax, kerosene, and a special petroleum oil, PD-428D, were tried on various kinds of bog weeds, 276 plots being treated. The results of many experiments have shown that many cranberry weeds can be killed in May and early June by treatments largely ineffective later in the season.

Paradichlorobenzene. It was observed in August 1940 that poison ivy (*Rhus Toxicodendron*) growing on areas of bog treated with 1200 pounds of this chemical to the acre and then resanded with half an inch of sand lost all its leaves, while cranberry vines on the same ground showed no injury. Cranberry bog plots with poison ivy were treated in September 1940, with amounts ranging from 800 to 5400 pounds per acre and then resanded with half an inch of sand. All these plots, except that which received 800 pounds per acre, showed a kill of three fourths of the ivy in the summer of 1941, with no injury to the cranberry vines or their crop. Paradichlorobenzene applied in June, July, and August, 1941, killed the ivy well, 1200 pounds per acre being as effective as greater amounts. A cover of three quarters of an inch of sand seemed necessary for the best results. Frost flooding two weeks after the chemical was applied did not seem to affect the kill of ivy.

Paradichlorobenzene, 1200 pounds per acre applied in June, July, and August and covered with three fourths of an inch of sand, killed 80 percent of considerable growths of chokeberry (*Aronia melanocarpa*), this weed losing all its leaves and its roots becoming brown and rotten in 12 days.

The following weeds endured paradichlorobenzene treatments as well as cranberry vines: Horse brier (*Smilax rotundifolia*), saw brier (*S. glauca*), small bramble (*Rubus hispidus*), coarse bramble (*R. villosus*), horsetail (*Equisetum*), asters (*A. spectabilis* and *A. multiflorus*), sphagnum moss, sensitive fern (*Onoclea sensibilis*), shield fern (*Thelypteris palustris*), bayberry (*Myrica caroliniensis*), sweet gale (*Myrica Gale*), wild bean (*Apios tuberosa*), red maple (*Acer rubrum*), hardhack (*Spirea tomentosa*), three-square grass (*Scirpus americanus*), spike rush (*Eleocharis tenuis*), and partridge pea (*Cassia chamaecrista*).

Naphthalene. Tests with naphthalene at 800, 1600, and 2400 pounds per acre were made in June, July, and August on poison ivy and other bog weeds. The chemical was broadcast by hand and covered with sand as in the paradichlorobenzene treatments. It failed to kill more than 10 percent of poison ivy even where it was applied in greatest quantity and had no effect on horsetail, hardhack, soft rush, reed canary grass, three-square grass, royal, sensitive, and shield ferns, or cranberry vines.

Ferric Sulfate. This year 32 plots with many kinds of cranberry bog weeds were treated with ferric sulfate at various rates. A carpet of young royal ferns on a peat-bottomed bog with poor drainage was killed with a broadcast treatment of 15 pounds per square rod, no cranberry vines or flower buds being hurt by it; 10 pounds per rod killed only 70 percent of the ferns and 20 pounds killed 8-10 percent of the cranberry branches.

One handful of ferric sulfate proved enough to kill 5-7 medium-sized cinnamon ferns. The vines around ferns treated with this amount under dry conditions showed no injury.

Ferric sulfate, 15 pounds per square rod, completely eliminated shield and sensitive ferns.

Single handfuls of ferric sulfate killed 2-4 clumps of soft rushes (*Juncus effusus*).

Spike rush (*Eleocharis*) was killed easily with 15 pounds of ferric sulfate or 35 pounds of ferrous sulfate to the square rod, but ferrous sulfate needs rain or a sprinkling of water to make it effective.

Ferric sulfate at 15-20 pounds per square rod must be used in late May or early June to be effective on rice cut-grass. This weed when 6 or more inches high, in July and August, tolerated a great deal of the chemical.

A little ferric sulfate at the base of each shoot was effective on wild bean. A handful was enough for at least 6 shoots.

Ferrous Sulfate. Dry ferrous sulfate, 40 pounds per square rod used early in June, killed 90 percent of long-leaved asters (*Aster spectabilis* and *A. Novi-Belgii*). The same treatment applied in July, when the asters were a foot high, killed only 25 percent.

Spike rush (*Eleocharis tenuis*) was controlled well with ferrous sulfate broadcasted at the rate of 40 pounds per square rod, June applications giving nearly complete kills while those made in July and August were less effective. Two competent growers reported the treatment as 95-100 percent effective when used in May.

Ferrous sulfate must be brushed off the cranberry vines when it is used in broadcast applications of 30 or more pounds per square rod.

Kerosene. Repeated experiments with kerosene showed the least injury to cranberry vines when it was applied before 10 a. m. or after 5 p. m. in June, July, and August. Mid-day applications, even with the air temperature below 80° F., injured cranberry tips and runners considerably. Recent tests of kerosene spraying in the early morning when the vines and weeds are wet with dew showed no injury to the cranberry vines, while the weeds seemed as sensitive to the kerosene as when sprayed under dry conditions.

Water white kerosene, 600 gallons per acre, gave 100 percent kill of loosestrife (*Lysimachia terrestris*) when applied before this weed was 5 inches high. The same kill was obtained later by mowing the taller loosestrife plants before spraying with kerosene.

Borax. Commercial borax, applied in July, 100 pounds per acre, killed Joe-Pye weed (*Eupatorium purpureum*) with little or no injury to cranberry vines. Heavier applications injured the vines.

Root Grub Flooding and Bog Weeds. Nine bogs flooded from mid-May to mid-July to kill grubs were examined in early September and late October to learn the effect of this flood on bog weeds. It had prevented no annual weeds from growing on the bogs but had shortened the season of several species so that they had failed to flower; others, like summer grass (*Panicum verrucosum*) and ragweed (*Ambrosia artemisiifolia*), had not attained normal growth but had flowered and seeded profusely; the trailing bramble (*Rubus hispidus*), rice cut-grass (*Leersia*), and wild bean (*Apios tuberosa*) had been reduced 90 percent; and the coarse bramble (*Rubus* sp.) and *Juncus* rushes had been killed entirely. Half the loosestrife (*Lysimachia*) and three fourths of the hair-cap moss (*Polytrichum*) had been killed where the water was over 18 inches deep, but these weeds had not been reduced much where the water was shallow. As many as 28 other species of perennial weeds grew more or less normally after the flooding.

COOPERATIVE CRANBERRY INVESTIGATIONS

Conducted by the Bureau of Plant Industry, United States Department of Agriculture, in cooperation with the Massachusetts Agricultural Experiment Station

H. F. Bergman, Senior Pathologist, Division of Fruit and Vegetable Crops and Diseases, in Charge

Development of Strains of Cranberry Resistant to False Blossom. (H. F. Bergman.) Nearly 1800 hybrid cranberry seedlings in pots were brought to East Wareham from Beltsville, Maryland, early in June 1941. This lot is part of the seedlings obtained from crosses made at East Wareham in 1938. They were set out temporarily on the State Bog and are to be transferred in 1942 to an area of new bog provided by the A. D. Makepeace Company of Wareham, Mass-

achusetts, under the terms of a memorandum of understanding drawn up with that company. Several other lots of seedlings from crosses made at East Wareham are set out in permanent locations on the State Bog where they will be allowed to grow until final assessment of their worth for propagation can be made.

Oxygen Content of Winter Flooding Water in Relation to Injury to Cranberry Vines. (H. F. Bergman.) Studies of the effects on cranberry vines of a lack of oxygen in the water during the winter flooding period were continued, in an attempt to correlate various types of injury with known low contents of dissolved oxygen over approximately known periods and to obtain additional data as to the conditions under which injury occurs. Three cylindrical sheet-iron tanks, about 5 feet in diameter, were placed on the State Bog, one each on sections planted with vines of Early Black, Howes, and McFarlin varieties. The bog was flooded on December 5, 1940, and froze over within a few days and remained frozen continuously until about the middle of March. Covers to exclude light and thereby prevent the liberation of oxygen by photosynthesis were placed on the tanks on January 18, 1941.

The importance of photosynthesis in maintaining the dissolved-oxygen content of the water on a winter-flooded bog covered with ice is shown by the course of this oxygen content outside and inside the tanks during the winter. The amount of dissolved oxygen in the water outside the tanks on Howes, Early Black, and McFarlin vines increased from 5.3, 6.4, and 6.8 cc. per liter, respectively, on January 15 to 7.2, 7.9, and 8.3 cc. per liter, respectively, on January 24 as a result of photosynthesis in the cranberry vines. A heavy snowfall on January 24 prevented photosynthesis by excluding light, while the consumption of oxygen by respiration of the cranberry vines and of organisms which decompose organic matter continued. As a result the dissolved oxygen in the water outside the tanks decreased to less than 2 cc. per liter, although probably for not more than 5 or 6 days. A heavy rain on February 7 removed most of the snow and the remainder froze into the ice. Thereafter, the dissolved oxygen in the water outside the tanks on Early Black and McFarlin vines increased rapidly, and by February 12 it had come up nearly to the same content as on January 24. The oxygen content of the water outside the tank on Howes vines remained near 2 cc. per liter until February 20 when it also began to increase.

The dissolved oxygen in the water inside the tanks on January 15 varied from 4 to 5 cc. per liter. Because of the exclusion of light by the covers, little or no photosynthesis could take place and the oxygen content of the water decreased steadily. By January 24 and from then until February 27 there was no dissolved oxygen in the water inside the tank enclosing vines of the Howes variety, and not more than 0.4 cc. per liter from February 27 until March 20. In tanks enclosing the other two varieties of vines there was less than 1 cc. of oxygen per liter of water for about a month from February 1 to March 1 except in the tank on Early Black vines where the oxygen content of the water increased to slightly more than 2 cc. per liter for a few days around February 12. On February 28 nine inches more water was pumped onto the bog which brought the oxygen content of the water up to more than 2 cc. per liter. Thereafter, except for a few days about March 13, there was never less than this amount of oxygen in the water. Soon after March 20 the ice went off the bog and the dissolved-oxygen content again increased.

The water was taken off the bog on April 1, 1941, and the tanks were then removed. Counts were made during the summer and autumn to ascertain the average number of flowers and fruits per upright, the percentage of buds killed, and the percentage of flowers that set fruit on vines of each of the three varieties both inside and outside the tanks where the dissolved oxygen content of the water

during the winter flooding period was known. The yield of berries of each variety inside the tanks and on measured areas outside was determined.

The effect of an insufficient supply or of complete deprivation of oxygen over a period of a month or more during the winter flooding period is shown clearly by the reduction in yield of berries from vines inside the tanks in comparison with vines outside. Furthermore, the yield outside but near the tanks was very much less than that from vines on slightly higher ground and therefore less deeply flooded. The yields, in barrels per acre, were as follows: Early Black, inside tank 28, outside near tank 34, on slightly higher ground 75; Howes, in the corresponding locations, 50, 72, and 110; and McFarlin, inside tank 39, outside on higher ground 81.

Although the dissolved-oxygen content of the water on the less deeply flooded areas during the winter was not determined, it has been found repeatedly that the oxygen content of water is less in deep places than in shallow, even a few inches making a significant difference, particularly when there is ice over the bog. It is probable, therefore, that the oxygen content of the water in the less deeply flooded "high" places did not fall below 2 cc. per liter for more than one or two days during the winter, if at all. This indicates that if the dissolved-oxygen content of the water is less than 2 cc. per liter for even a few days the yield is greatly reduced. A longer period of oxygen deprivation caused a further reduction in yield, but even within a variety the reduction was not proportional to the length of time during which the oxygen deficiency existed. Prolonged oxygen deficiency affected vines of different varieties differently. There was no oxygen in the water inside the tank on Howes vines for nearly two months; yet these vines yielded better than Early Black vines inside a tank in which the oxygen in the water was less than 1 cc. per liter for not more than a month and approached exhaustion for about two weeks only. This probably is because the Early Black vines had been badly injured by a lack of oxygen in the water during the flooding period of the winter of 1939–40 and therefore were more susceptible to injury.

The first effect of an oxygen deficiency during the winter flooding period is to reduce the number of flowers that set fruit. Injury of this kind apparently may occur if there is less than 2 cc. of dissolved oxygen per liter in the water for as short a time as 3 or 4 days. In all three varieties the percentage of flowers setting fruit was lowest on vines inside the tanks, where the oxygen deficiency was greatest, and was lower on vines in slightly deeper water than on those most shallowly flooded, although in some cases the difference was small.

A greater deficiency of oxygen or a deficiency over a longer time causes the death of flower buds and then of the uprights on which the flowers are borne. The percentage of dead buds on vines of all three varieties in the areas outside but near the tanks was considerably greater than it was on vines on slightly higher ground. In the Early Black and Howes varieties the percentage of dead buds on vines inside the tanks was slightly less than on those outside, whereas it should have been greater. One reason for this discrepancy may be that more of the flower buds on vines inside the tanks than on those outside were killed at such an early stage of development that they were not detected when the counts were made. This is indicated by the lower average number of flowers per upright for these varieties on vines inside than on those outside the tanks. Another reason is that in making the counts only flowering uprights were taken; no attention was paid to sterile ones, a considerable proportion of which probably were flowering uprights on which the buds had been killed at a very early stage of development. For the same reasons the values for the percentage of flowers setting fruit on vines of the Early Black and Howes varieties inside the tanks are higher than they would otherwise have been.

The average size of berries from vines inside the tanks was smaller than that of

berries from vines just outside the tanks or from vines on slightly higher ground. Berries of the Early Black variety showed the greatest difference. Those from vines inside the tank averaged 158 to the cup (½ pt.); from vines just outside, 118 (average of 93 counts); and from vines on slightly higher ground, 110 (20 counts). The average number of berries per cup for the other two varieties was as follows: Howes, inside tank 115, outside near tank 105, outside on slightly higher ground 100; McFarlins, inside tank 94, outside near tank 94, on slightly higher ground 84. Many berries failed to grow to a size large enough to be picked. The proportion of these berries was greater from vines inside the tanks or from vines outside near the tanks than from vines on higher ground.

The reduction in the size of picked fruits and the failure of berries to grow to a size large enough to be picked probably is due to an inadequate food supply during the summer because of injury to the leaves of the preceding season which reduced their capacity to synthesize carbohydrates. Vines of all three varieties inside the tanks lost more of their old leaves than did vines outside. This was true especially of Early Black which lost nearly all the old leaves from vines inside the tank. Even when old leaves remained on the vines, many of them were injured and probably their effectiveness in the formation of carbohydrates was greatly reduced.

The following conclusions are drawn: Injury to cranberry vines occurs when the dissolved-oxygen content of the water falls below 2 cc. per liter. This happens apparently only when the ice on a winter-flooded bog is covered with snow, which excludes light and thereby prevents photosynthesis and the resultant liberation of oxygen which ordinarily keeps the oxygen content of the water high enough to prevent injury. The injurious effect on cranberry vines of a lack of oxygen for several days to a few weeks is shown ultimately in the reduction of the crop. Reduced yields are the direct result of (1) reduction in the number of flowers setting fruit, (2) death of flower buds and flowering uprights, and (3) reduction in the size of fruits, both those harvested and those too small to pick.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

Studies on Chocolate-Flavored Milk. (W. S. Mueller.) The study of chocolate-flavored milk, with especial emphasis on its nutritive value, continues to be a major project in this department. For a long time it had been assumed that the well-known nutritive properties of plain milk were also present in chocolate-flavored milk. In 1937 it was discovered that milk containing 2.5 percent or more of cocoa was not equal in nutritive value to plain milk, when fed to white rats. Since then experiments have been in progress to learn more about the various constituents of cocoa and their possible effects upon the nutritive value of the milk. In addition to the nutritional studies, investigations on improving the method for processing chocolate milk are in progress.

1. *The Effect of Cocoa Upon Digestibility of Milk Proteins.* (L. D. Lipman and W. S. Mueller.) The addition of cocoa to whole milk powder in quantity equivalent to approximately 3.6 percent by weight on a fluid milk basis reduced the digestibility of the milk protein 7.8 percent. The kind of cocoa, Dutch or American-process, and the inclusion of 7.1 percent of cocoa fat in the ration, did not significantly affect the percentage reduction. Proteins of the Dutch and American-process cocoa were found to be 38.1 and 44.5 percent digestible, respectively. The results of this study were published in the *Journal of Dairy Science* 24, May 1941.

2. *The Significance of Tannic Substances and Theobromine in Chocolate Milk.* (W. S. Mueller.) The relative toxicity of pure theobromine, pure tannic acid, and two cocoa powders varying in content of tannic substances was determined by feeding these substances in a basal diet to white rats. Theobromine was non-toxic to albino rats when the ration contained 0.27 percent of this alkaloid, and tannic acid was toxic when the ration contained 2 percent of this substance. These amounts of tannic acid and theobromine in the diets were equal to those in a chocolate milk made with 3.6 percent cocoa powder which contained 12.15 percent tannic substances and 1.7 percent theobromine. A cocoa powder containing 12.15 percent of tannic substances was more toxic than a cocoa powder containing only 2.67 percent of tannic substances, but was less toxic than pure crystalline tannic acid. A concentrated extract of cocoa was non-toxic to rats when fed at the rate of 8 percent of the ration. The hemoglobin levels of the blood of rats fed theobromine, crystaline tannic acid, and cocoa powder containing varying amounts of tannic substances did not vary from the normal enough to be of any significance. Results from this study indicate that the toxicity from cocoa can be greatly reduced by selecting a cocoa or chocolate which is low in tannic substances, or preferably by using an extract of cocoa as the flavoring material when feasible.

3. *The Availability of the Iron of Cocoa and of Additional Iron when Associated with Cocoa.* (F. Kinder, H. S. Mitchell, and W. S. Mueller.) This study is reported by the Department of Home Economics Nutrition.

4. *Effect of Adding Cocoa to Cow's Milk on the Utilization of Calcium and Phosphorus.* (M. R. Cooney and W. S. Mueller.) This study is reported by the. Department of Home Economics Nutrition.

5. *The Bacteriology of Chocolate Milk, Chocolate Syrup, and Cocoa Powders* (R. W. Swanson, J. E. Fuller, and W. S. Mueller.) This study is reported by the Department of Bacteriology.

6. *Effect of Cocoa on the Vitamin C Content of Milk.* (W. S. Mueller.) Vitamin C is present in fresh raw milk to the extent of 12 to 20 mg. per quart. If this could all be retained, milk would be a significant source of vitamin C, since the higher figure is about half the daily requirements of an adult. Therefore, the handling of milk from the time it is drawn until it is consumed, in a manner which will conserve the vitamin C, is an important problem today.

If chocolate milk is substituted for plain milk, it is important to know what effect the cocoa has upon the retention of vitamin C. Preliminary studies on the relative retention of vitamin C in plain milk and chocolate milk have been made, using the 2, 6-dichloro-phenol-indophenol in both visual and electrometric titrations. Results of these studies indicate that the addition of cocoa to milk hastens the destruction of vitamin C. When both milks were stored, under identical conditions, the plain milk lost 22 percent of the original vitamin C, while the loss for chocolate milk was 77 percent. This difference in loss of vitamin C is typical of the results obtained. Studies are also being made to determine which method is most suitable for measuring the vitamin C content of chocolate milk.

7. *Effect of Cocoa on the Coagulation of Milk.* (W. S. Mueller.) It has been reported by a foreign investigator that cacao bean contains an enzyme with rennet effect. Dry, it withstands heating to 248°-284° F. and may, therefore, be found in cocoa powder. The optimum temperature of the enzyme is 149° F. and the optimum pH is below 6.3. By heating a suspension of cocoa powder in water (176° F.), the enzyme will be destroyed.

Since the knowledge of this enzyme may be of practical interest to the consumer as well as to the manufacturer of cocoa, a study was undertaken to deter-

mine whether cocoa powders commonly sold in this country contain such an enzyme. In preliminary studies 25 samples of cocoa powder have been investigated. When one percent of cocoa powder, by weight, was added to good quality milk (.16 percent acidity), only one cocoa powder coagulated the milk shortly after heating at 149° F. for 30 minutes. Further investigation will be made, using milk of higher acidity and of a low protein stability, and also adding a larger amount of cocoa to the milk.

8. *The Effect of Various Methods of Pasteurization on Chocolate Milk.* (W. S. Mueller and A. M. Shipley.) Further experiments in pasteurizing chocolate-flavored milk by the Electropure process substantiate in a general way the results of last year. However, in the latest trials, the Electropure method was more efficient in the reduction of the bacteria count of highly viscous chocolate milks.

Cooperative Study with the American Dairy Science Association Committee on Methods for Determining the Curd Tension of Milk. (W. S. Mueller.) The final report of the committee on methods of determining the curd tension of milk was published in the *Journal of Dairy Science*, 24, September 1941.

Improving the Flavor and Keeping Properties of Milk and Some of its Products. (W. S. Mueller and M. J. Mack.) A major flavor defect of orange or lemon ice and sherbet is the development of terpene odors and flavors, as a result of the oxidation of the oil in the flavoring material. It seems logical that this flavor defect could be prevented or minimized by the addition of an antioxidant. Therefore, the antioxygenic effect of oat flour and of a concentrated extract of oat flour was studied by adding 0.5 and 0.1 percent of these substances, respectively, to lemon and orange ices. Fresh orange and lemon juice were used as the flavoring materials. The control samples developed a harsh flavor after four days, while the samples containing the antioxidants had a typical orange and lemon flavor for several weeks. In the concentrations used, the concentrated extract of oat flour was slightly more effective than the powdered oat flour. A protective action was also noted when a sugar which had been treated with the oat flour concentrate was added to the orange and lemon ices.

Cocoa flour was found to be an effective antioxidant when added directly to milk. Also cocoa flour and oat flour possessed antioxygenic properties when used for treating paper milk-container stock.

Factors which may affect the solubility of the antioxidant oat flour in ice cream mix and milk are being investigated. The effect of temperature of the milk at the time the oat flour is added has been studied. No significant differences were noted for temperatures ranging from 50° to 160° F.

The Use of Corn Syrup Solids in Ice Cream and Ices. (M. J. Mack and J. H. Nair.) The use of dried corn syrup as a sweetener in frozen dairy products was discussed in a previous publication. (Corn Syrup Solids Improve Frozen Dairy Products. Lynn R. Glazier and Merrill J. Mack. *Food Industries*, June 1941, p. 68.) The replacement of 20 to 25 percent of the sucrose ordinarily used in ice cream by corn syrup solids was found to affect but slightly the sweetness of the product and to improve somewhat the body and texture and melting characteristics of the ice cream. Consumer acceptance of ice cream containing sucrose and corn syrup solids seemed to be slightly greater than of that containing sucrose as the only sweetening agent. During the first part of the study it became evident that factors other than the sugar content of ice cream may affect the apparent sweetness of the product. Therefore, the project is being continued to study some of these factors.

Preliminary results indicate that the apparent sweetness of ice cream may be affected by such factors as the source of butterfat, the ratio of fat to serum solids,

the mineral salts present, and the melting characteristics of the product. Other factors are also involved, such as the serving temperature, the type of flavoring used, and the ratio of solids to sugar in the ice cream.

A Study of New Stabilizing Materials for Ice Cream. (M. J. Mack and A. M. Shipley.) Several new stabilizers have recently been developed and already are used to some extent in ice cream. The stabilizer employed affects a number of properties, such as the viscosity, titratable acidity, and whipping ability of the mix, and the flavor, body and texture, and melting properties of the ice cream. The object of this investigation is to compare the effectiveness of the new stabilizers with those already known to be desirable in ice cream.

Among six stabilizers thus far observed, two were as effective as gelatin or sodium alginate in producing mix viscosity and firmness of body in ice cream. They allowed satisfactory whipping of the mix and permitted normal melting of the product. The chief difficulty thus far encountered is that some of the newer stabilizers are somewhat lacking in solubility. The work will continue with a study of the effects of each active material employed, with the object of finding a combination of stabilizing materials more satisfactory than those now available.

The Appearance of Melted Ice Cream. (M. J. Mack.) The melting characteristics of ice cream have recently received more consideration, as is evidenced by the fact that the new score card approved for ice cream by the American Dairy Science Association allots 5 points to this item. Severe defects in melting appearance usually are due to loss of stability of the casein in the ice cream, while minor defects may be due to other causes.

Slight increases in the acidity of mixes cause ice cream to appear curdy or "whey off" when melting, if normal homogenization pressures are maintained. Standardization of the acidity by the addition of some suitable alkaline material does not injure the melting appearance in ice cream of average composition unless the original acidity is greater than approximately 0.24 percent. The melting characteristics are affected to a lesser degree by such factors as the components used, the percentage composition, the methods of freezing, and so on.

A Comparison of the Electric and Vat Methods of Pasteurization. (L. D. Lipman, J. H. Frandsen, and H. G. Lindquist.) Split batches of raw milk were pasteurized in an electric pasteurizer at 162° for 16 seconds, and in a spray vat at 143° for 30 minutes. The following conclusions may be drawn.

1. The reduction in vitamin C content of milk was less rapid in the electric-pasteurized milk than in raw or vat-pasteurized milks.

2. The electric method gave better, that is less, phosphatase units than the vat method.

3. Vat-pasteurization decreased the cream volume, while the electric method gave the same cream line as that of the raw milk. However, the difference between the two methods of pasteurization was so small that no definite conclusions should be drawn as to which of the two methods results in the smaller decrease in cream volume.

4. There was no significant difference in the efficiency of bacterial reduction between the vat and electric methods of pasteurization. With some milks the electric method seemed to show the higher percentage kill, whereas with other milks the vat method seemed to show the higher percentage kill. A probable explanation for this is that the types of bacteria or bacterial flora present in the milk will affect the percentage killed by pasteurization. For example, evidence seems to show that thermophilic bacteria are killed by the high-temperature-short-time pasteurization but survive and may grow at vat-pasteurization temperatures. The reverse seems to be true with the thermoduric types of bacteria.

5. Electric-pasteurized milk became oxidized less rapidly, less frequently, and to a lesser degree than did vat-pasteurized milk. A cooked flavor was found more often and more pronounced in vat-pasteurized milk than in electric-pasteurized milk.

6. Generally it can be said that electric pasteurization (high temperature-short time) of milk will tend to prevent development of oxidized and cooked flavors, and such milk will have a higher flavor score than vat-pasteurized milk at the end of 48 hours.

A Study of the Efficiency of the McCormick-Deering Cream Separator (Standardizer.) (A. M. Shipley and J. H. Frandsen.) In 1938 a report was given of a study of the suitability and practicability of the DeLaval Multipurpose Separator. In some further work on this project, tests have been made on the McCormick-Deering Cream Separator. The following results were obtained:

	Before	After
Sediment	9.8	9.8
Flavor Score	22.5	23.25
Fat (percent)	3.0	4.0
Skim (percent)	—	.01
Total solids (percent)	11.395	12.35
Bacteria per c. c.	1500	2400
Curd tension	60	57.5
Creaming (pint bottle)	2 inches	2½ inches

Standardization, in addition to providing a milk of desired fat content, seems also to give milk of slightly better flavor. Standardization with a mechanical standardizer is, in our judgment, more practical and economical than standardization by siphoning or foremilking.

Some Factors Affecting the Wheying Off of Cultured Buttermilk. (L. R. Glazier and H. G. Lindquist.) When cultured buttermilk is allowed to stand in storage, it frequently separates into a layer of curd and whey. In this study it was found that the higher the developed acidity, the less curd separation and wheying off occurred. Pasteurization at a temperature of 200° F. was more desirable for the milk to be used for culturing than was pasteurization at 180° F., and temperatures below 180° F. should be avoided. Storage temperatures as high as 50° F. should be avoided. Storage at 33° F. gave the best results of any of the temperatures used, in preventing wheying off of buttermilk in storage. The longer the buttermilk is held, the more separation and wheying off there is likely to be. Therefore, smaller batches should be made in order to eliminate long storage periods. (Published in *Milk Plant Monthly*, 30 (5): 27-30, 1941.)

DEPARTMENT OF ECONOMICS

Alexander E. Cance in Charge

Land-Use Problems in Massachusetts in Relation to a Balanced Program of Land Utilization. (David Rozman.) The major phase of this project has been completed and the results presented for publication as Experiment Station Bulletin 387. This study deals with the interrelationship of major uses of land on a State and local basis. To an analysis of the historical trend in agricultural and forest land uses is added consideration of other important land uses such as recreational, part-time farming, residential, and industrial. The summary and main conclusions are as follows:

1. The classification of land on the basis of soil and topography indicates that 50.2 percent of the total area of the State is suitable for agricultural utilization.

2. The percentage of agricultural suitability varies from 31 percent in Barnstable County to 62.7 percent in Worcester County.

3. In 1880, before the decline in agricultural land use set in, 41.4 percent of the State area was represented by improved farm land. In 1940 this proportion had declined to 15.4 percent.

4. The major local land-use factors responsible for the decline of improved farm land relate in varying degrees to changing types and systems of farming; soil erosion and deterioration; non-resident land ownership; the disappearance of town industries; and the growth of residential, recreational, commercial, and other more intensive uses of land.

5. Non-resident ownership of about one-third of all land in rural towns has contributed to the increasing amount of land under wooded cover.

6. Of the total State area, 64.3 percent is under wooded cover. The highest proportion is in Barnstable and Berkshire counties, 73.1 and 71.8 percent, respectively; the lowest in Essex and Middlesex counties, 52.0 and 57.8 percent, respectively.

7. In the towns below 10,000 population there are 89 with no existing local industries. In each of 87 of the remaining 184 towns, local industries provide employment for less than 100 persons.

8. The demand for more intensive uses of land has affected farming through higher land values and taxes.

9. The average value per acre of farm land and buildings is $37.38 in the lowest third of the towns below 10,000 population. In the highest third the average value is $284.57 per acre.

10. From the standpoint of land-use pattern and land-use adjustments needed, five types of rural towns are indicated in Massachusetts:

A. Towns characterized by predominantly poor land, declining population, limited amount of agricultural land utilization, and extensive areas under wooded cover.

Major adjustments needed: Extension of public ownership of forest land, elimination of isolated settlement, development of recreational facilities, possible discontinuation of the town as an independent political unit.

B. Towns with a fair agricultural background, experiencing recent dislocation in local industries.

Major adjustments needed: Realignment of town expenditures, fuller utilization of land resources for agriculture and other uses, rehabilitation of industrial opportunities.

C. Towns with favorable physical background for well-rounded agricultural land utilization.

Major adjustments needed: Conservation of soil, better adaptation of crops, and better care of woodlots.

D. Towns with receding agricultural land utilization as a result of expansion in more intensive uses of land.

Major adjustments needed: Prevention of increase of idle land held for speculative purposes, primarily by more equitable taxation of land used in agriculture.

E. Towns with a balanced system of agricultural and other land uses.

Major adjustments needed: Maintenance and improvement of local conditions through farsighted policies of local people and their planning agencies.

Problems of Rural Youth in Massachusetts. (David Rozman, Gilbert Meldrum, Ruth E. Sherburne.) This study was undertaken during the past year in cooperation with the United States Department of Agriculture to determine and analyze the most important problems of rural youth in Massachusetts. Nearly 600 schedules were obtained in selected towns in four counties, including young people, both in school and out of school, ranging in age from 16 to 25. For 40 percent of the boys the main problem had to do with finding a job, making a living, or getting started in farming. For one-fourth of the girls the major problems were also economic. Of the problems mentioned by both boys and girls, 25 percent concerned education and vocational guidance.

The results of this study have been analyzed and presented as Experiment Station Bulletin 386.

DEPARTMENT OF ENGINEERING

C. I. Gunness in Charge

Cranberry Storage Investigation. (C. I. Gunness, H. J. Franklin, and C. R. Fellers.) The storage of Early Black cranberries in a modified atmosphere was continued during the 1941 season. All the berries were picked and stored on September 8 and removed from storage and screened on November 14. Three lots of berries were stored at 35 degrees and three lots at 45 degrees. One lot at each temperature was kept in normal atmosphere, one lot in an atmosphere containing 5 percent carbon dioxide and 2 percent oxygen, and one lot in an atmosphere containing 10 percent carbon dioxide and 10 percent oxygen. The berries stored in modified atmospheres were kept in sealed sheet iron cabinets having a capacity of 2 barrels each. Means were provided for removal of excess carbon dioxide by circulating the air from the cabinets through a solution of sodium-hydroxide. Excess moisture was removed from the cabinets by circulating the air through calcium chloride.

Apparently this process was ineffective as the berries were covered with moisture when the cabinets were opened at the end of the test.

Berries stored in normal air at 35 degrees and 45 degrees showed the usual differences in storage loss which have been observed in former years. Those stored at 35 degrees showed a storage loss of 4.7 percent, while those at 45 degrees showed a loss of 11.6 percent. All the berries stored in the modified atmospheres showed greater losses than those stored in normal air. It is not known, however, whether this increased loss was due to the composition of the atmosphere or to the excessive moisture in the cabinets. The experiment will have to be repeated next year with more efficient equipment for removing excess moisture from the cabinets.

Berries stored in normal air developed very much better color at 45 degrees than at 35 degrees. Berries stored in modified atmospheres on the other hand, developed no better color at 45 degrees than at 35 degrees; and berries stored in modified atmospheres at 35 degrees were not as well colored as those kept in normal air at 35 degrees.

Apple Storage Investigation. (C. I. Gunness in cooperation with Department of Pomology.) A small room for the storage of apples in a modified atmosphere was prepared during the summer of 1940 and filled with McIntosh apples that fall. The room had a small leak and it was not possible to reduce the oxygen content to the desired 2 percent. Considerable variation in temperature increased air circulation through the leak, and it was not possible to reduce the

oxygen below 11 percent. The results obtained with the storage were, therefore, unsatisfactory, the fruit on removal being in about the same condition as fruit kept at 32 degrees in a normal atmosphere.

During the past summer the leak was stopped and a new cooling unit installed with a sensitive thermostat. The room is now operating with an atmosphere of 5 percent carbon dioxide and 2 percent oxygen. Results will not be available until the room is opened in the spring.

Frost Protection on Cranberry Bogs. (C. I. Gunness.) The wind machine used for frost protection was moved to a dry bog in the spring of 1941. It was operated both in the spring and in the fall. The results were in general unsatisfactory in that protection was given over too small an area.

Poultry House Investigation. (C. I. Gunness and W. C. Sanctuary.) The investigation on the operation of electric brooders in colony houses was continued during 1941. The purpose of the investigation was to see whether litter could be kept dry in a brooder house through the use of soil heating cable. Very wet sawdust litter was placed in the houses and while the litter in the house equipped with soil cable was drier than in the others, it was not sufficiently dry to be considered satisfactory. It was felt, however, that the litter was too wet at the start to make a fair test of the effect of the soil cable. Good chicks were reared in spite of the damp litter conditions. The test is being repeated this year.

Ceiling temperatures were taken during the winter months of 1941 in insulated and non-insulated pens through the use of thermocouples. Ventilation was adjusted so as to keep the same temperature in insulated and uninsulated pens. It was found that on cold nights the ceiling temperatures in insulated pens would run one degree lower than air temperatures within the pen, while in uninsulated pens the ceiling temperature would run 4.5 degrees lower than the air temperature. This would indicate that insulated pens are more comfortable for the birds even though there may be but slight difference in air temperatures.

Observations taken during the late summer showed ceiling temperatures from 5 to 13 degrees higher in uninsulated pens than in insulated pens with equal air temperatures. In sections where the black composition roof had been painted with aluminum paint, the ceiling temperature in uninsulated pens was reduced from 85 degrees to 82 degrees on the rear slope when compared with sections which had not been painted. In insulated pens the aluminum paint produced a difference of 3 degrees in ceiling temperatures on the rear slope. On the front slope the black surface gave a ceiling temperature of 101 degrees in the uninsulated pens with a temperature of 92 under the aluminum paint. In the insulated pen the black gave 88 degrees and the aluminum 85 degrees on the front slope.

DEPARTMENT OF ENTOMOLOGY

Charles P. Alexander in Charge

Investigation of Materials which Promise Value in Insect Control.

Oil sprays for dormant applications. (A. I. Bourne and W. D. Whitcomb.) The early season of 1941 was unusual in many respects. March was characterized by cold, windy weather with the average temperature below normal and snowfall above the average. April, however, was marked by abnormally high temperature which persisted throughout the month and culminated in the peak of 90 degrees reached on the 20th. The transition from winter to spring was very

abrupt, and since it was not accompanied with the usual amount of rainfall the snow and frost disappeared rapidly and the soil dried quickly, furnishing excellent ground conditions for early spring spraying. Plant and animal life responded to the unusually warm weather. Seasonal development began early and progressed rapidly. In most orchards the period for delayed dormant application of oil sprays was very brief so that many growers were unable to complete this application before bud development progressed to the pre-pink stage. In the college orchards the delayed dormant period was passed in 4 to 5 days, and some blocks received the pre-pink spray 3 days after the delayed dormant. In the experimental blocks the trees had received the dormant, delayed dormant, pre-pink, and pink sprays by April 28 in contrast to 1940 when in the same blocks the delayed dormant spray was applied April 29. Very few instances of damage to fruit buds or foliage by oil sprays were observed or reported in spite of the unseasonable temperature. This was probably due in large measure to the relatively small amount of oil spraying done.

In the cooperative project with the Dow Chemical Company on the investigation of DN sprays, attention was focused on the relative tolerance of various types of ornamentals (coniferous and deciduous) to dormant applications of DN–oil sprays. In these tests different concentrations of dinitro-ortho-cyclo-hexylphenol (DNOCHP) compounds were used. None of the common deciduous ornamentals showed any ill effects from the application aside from a slight retardation in some cases. Moderate burning was noted on Irish juniper and more serious injury resulted on rhododendron and laurel.

In strictly dormant application on apples for the control of overwintering eggs of European red mite, 2 dry-mix DN compositions containing 40 percent DNOCHP and DNOC (dinitro-orthocresol) respectively were combined with 2 standard types of commercial oil sprays. Application of a DNOCHP–oil solution of 7.9 pH caused no injury to fruit or leaf buds nor retardation in development. A DNOCHP oil solution of 6.6 pH caused noticeable retardation in development but no actual killing of buds. The DNOC oil solutions of 5.8 pH and 4.8 pH both caused marked retardation of bud development. The combinations containing the DN compounds were somewhat less effective against red mite eggs than were the oils alone.

Counts of young mites on the test trees showed 1,660 mites per 100 spurs following DNOCHP–oil emulsion; 675 following DNOC–oil emulsion; and 465 following the oil emulsion alone. Check trees showed 13,055 mites per 100 spurs. Following DNOCHP+miscible oil, counts showed 20 mites, DNOC+miscible oil, 80 mites; and miscible oil alone, 15 mites per 100 spurs.

In applications at Waltham on April 8, 1941, no noticeable injury resulted to bark or twigs from DN–oil mixtures having a pH value of 8.0, 7.45, or 6.75. All of the mixtures retarded bud development slightly, and when trees were in full bloom there was slightly more retardation on McIntosh and Wealthy from the alkaline mixture than from the more acid mixture. It was also observed that a dinitro-orthocresol–oil mixture retarded bud development slightly less than dinitro-ortho-cyclo-hexylphenol in combination with either alkaline or acid oil emulsion.

All of the sprays gave good control of the European red mite eggs and reduced the average number of living mites per spur on April 30 by 90 percent or more. No significant differences between the materials resulted, but the dinitro-orthocresol–oil mixture, which is generally considered safer than the DNOCHP mixture, gave very satisfactory control of the red mite.

At the college, incidental records on the overwintering eggs of aphids, including heavy infestations on birch and pine and moderate infestations on several ornamentals, showed practically perfect kill following the use of DN compounds.

The contrast between sprayed and unsprayed specimens of Viburnum was conspicuous. (See page 54.) The foliage of unsprayed checks was tightly curled and distorted and the the plants were of little use as ornamentals, while on the sprayed plants freedom from aphid attack allowed full and perfect foliage, a condition that is rarely seen in this region.

Dormant application of a commercial oil emulsion at 5 percent dilution combined with dry-mix DNOCHP gave excellent control of oystershell scale on lilac and willow. Light to moderate infestations were eliminated. On heavy infestations with thick encrustation of the bark, some slight hatching took place but from a commercial standpoint it was negligible.

Summer Treatments for the Control of European Red Mite. (A. I. Bourne and W. D. Whitcomb.) Another abnormal feature of a very unusual season was the comparative scarcity of European red mite in most orchards in midsummer and late summer. The infestation was negligible in the college orchard. A heavy outbreak in a Berkshire County orchard offered opportunity for checking the efficiency of a DN dust (a 1.7 dicyclohexylamine salt of DNOCHP). The red mite population before dusting amounted to 54.8 mites per leaf. Counts 24 hours after treatment showed an average of 9.6 mites per leaf, and similar counts made 8 to 9 days after treatment showed an average of one mite per leaf an 82.5 percent reduction in 24 hours and a 98.1 percent reduction after an 8- to 9-day period.

Tolerance tests of this dust and of a DN spray containing 20 percent of the toxicant designed for summer use, on 28 different types of fruit and shade trees, ornamentals, and garden plants subject to mite attack showed no injury following either the dust or the spray.

In August, tests of new materials for the control of the European red mite on apple were made both at a commercial orchard in Gleasondale and at the Waltham Field Station. The most effective material was a dicyclohexylamine salt of dinitro-ortho-cyclo-hexylphenol mixture containing 20 percent of the toxicant together with dispersing and wetting agent. In four tests of this material at the rate of 20, 24, and 30 ounces in 100 gallons of spray, the average reduction of living red mites was 94.2 percent. There was no significant difference between the dosages used, indicating that the smallest amount (20 ounces in 100 gallons) was adequate. A 40 percent DNOCHP mixture used at 4 ounces in 100 gallons gave 88.1 percent reduction and apparently lacked sufficient wetting agent. A DN dust containing 1.5 percent of the toxicant averaged 95.3 percent reduction when applied from both sides of the tree and reduced the living mites 89.3 percent when the tree was dusted from one side only.

Five tests of spray materials containing rotenone averaged 88.5 percent reduction, including one moderately effective combination which gave only 78.7 percent reduction. A pyrethrum spray containing an excellent spreading agent was one of the most effective materials used and reduced an infestation of 20.04 red mites per leaf to 0.69 live mites per leaf, a control of 97.05 percent. A mixture containing ricin, the toxic ingredient in castor-bean, was the least effective material used. None of the materials caused injury to the fruit, bark, or foliage which was abnormally "hard" following the summer drought.

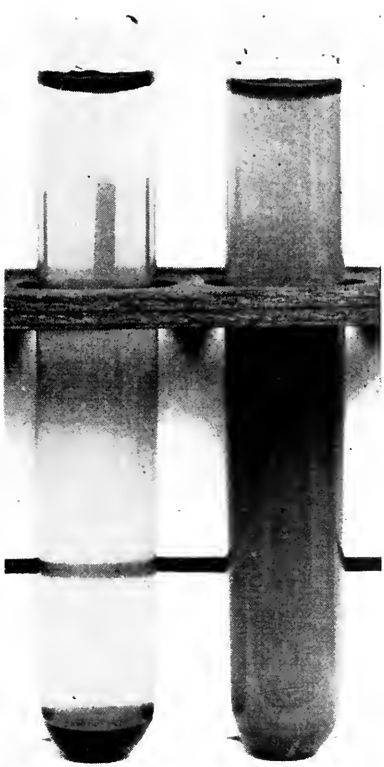


Figure 1

Left: Merrimac fine sandy loam.

Right: Memphis silt loam.

Equal weights of soil dispersed in equal amounts of water and allowed to settle the same length of time.

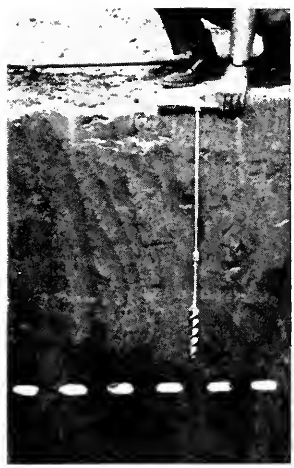


Figure 2

Topsoil 3.5 feet deep, accumulated at the foot of a short cultivated slope through the action of sheet erosion. (Broken white line separates topsoil and subsoil.)

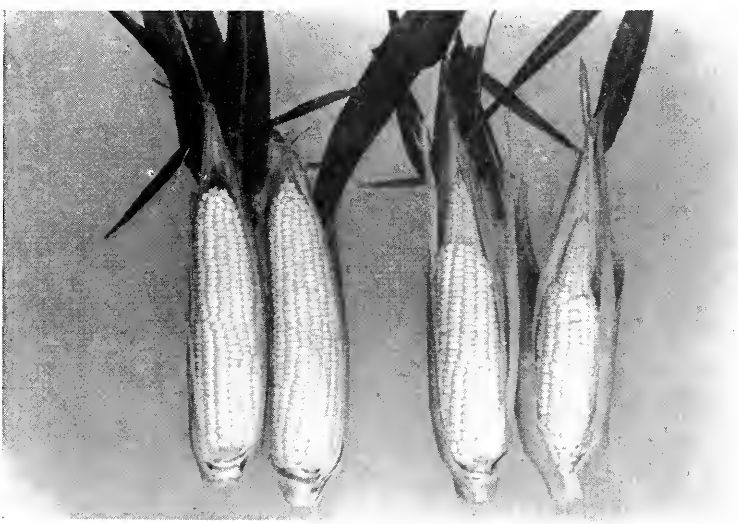
Viburnum

Upper Branch Untreated: Leaves tightly curled, twigs deformed.
Lower Branch Sprayed with DN: Free from aphids, leaves normal.

Defoliation of Rose by the Common Red Spider

Plant at left sprayed

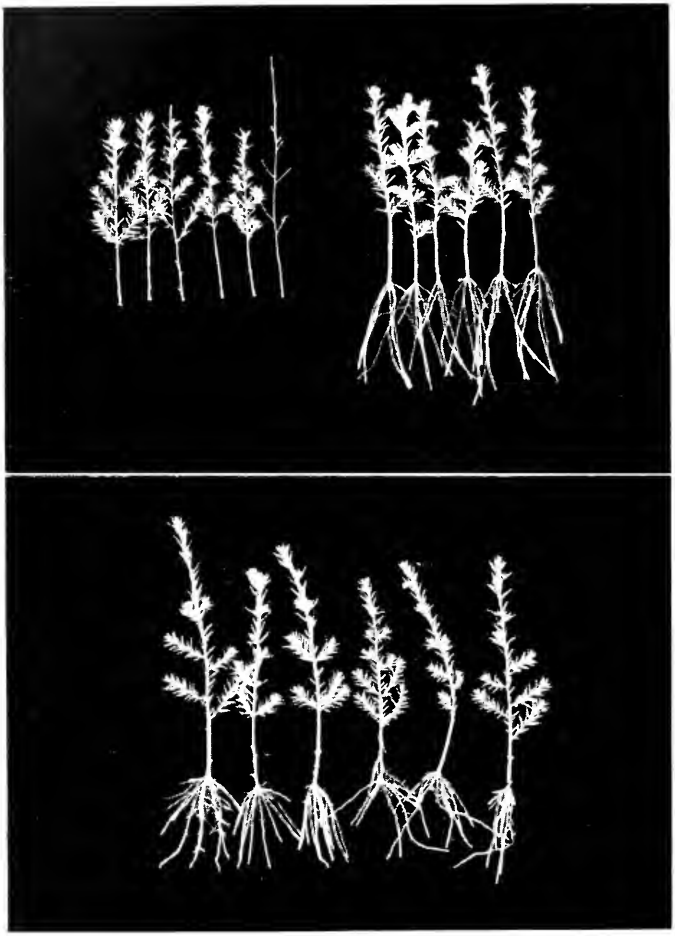
Plant at right unsprayed



Injury to Ears of Sweet Corn from Oil—Pyrethrum applied for control of Corn Ear Worm

Left: Not treated

Right: Treated



Rooting of Cuttings of Canadian Hemlock

Top: After 10 weeks at 75° F.

Left: Not treated.

Right: Treated with Hormodin A, 30 BTI units for 24 hours.

Bottom: After 15 weeks at 65° F.

Treated with Indolebutryric Acid, 7.5 mg. 100 c. c. for 24 hours.

Summer Sprays for Apples. (A. I. Bourne in cooperation with Departments of Pomology and Botany.) Studies of the value of modifications of the standard spray program were continued. The yield was light, and the prolonged drought in the early season greatly influenced the prevalence of disease, particularly apple scab. The standard spray program, involving lime-sulfur in all sprays through the calyx with wettable sulfur thereafter, was contrasted with a similar program with the addition of a midbloom application of wettable sulfur, and an optional standard in which no lime was used in the cover sprays. The standard schedule was also contrasted with a program of wettable sulfur throughout the season. Lead arsenate was used in all applications except the pre-pink and midbloom sprays. The dosage was 4 pounds to 100 gallons in the calyx, and 1st and 2d cover sprays; 3 pounds in the pink and 3d cover sprays, and 2 pounds in the 4th cover spray. Liquid lime-sulfur was used at the rate of 1½ gallons per 100 and wettable sulfur at 8 pounds per 100 gallons.

The pathologist reported that scab infection was appearing on the foliage of McIntosh check trees in the period of May 23 to 26, and a few infected fruits were observed May 31. On the sprayed trees the spur leaves and fruits were evidently protected by the pre-blossom sprays and the infection was confined to the shoot leaves. The record of McIntosh fruit at harvest supported these observations. The fruit from unsprayed trees showed 44 to 45 percent scab, while on sprayed trees it varied from 0 to 1.8 percent.

The season also was not conducive to spray injury on either leaves or fruit. Distinct injury, however, occurred in all plots where liquid lime-sulfur was applied although this was not of so serious a nature or extent as in years of more normal rainfall. Russeting of fruit was noted in all plots where lime-sulfur was applied.

The control of insect pests was consistent throughout the entire orchard and there was no significant difference between the standard program and the modified schedules. The record of unsprayed McIntosh fruit was illuminating. Three apples, or 0.6 percent were clean; 80 to 81 percent of the fruit was scarred by curculio, and nearly 50 percent damaged by codling moth. Scab occurred on 44 to 45 percent of the apples (in a season very unfavorable for its development) Detailed counts showed that on nearly 50 percent of the fruit there were injuries by three or more insects or diseases on the same apple.

Control of Cabbage Maggot. (W. D. Whitcomb, Waltham.) Definite information showing that one of the largest sources of cabbage maggot flies in the spring is late-planted cruciferous crops was obtained by sifting the soil in a six-inch square and six inches deep around roots of cabbage, broccoli, and turnip which had remained in the ground over winter. These plants were apparently infested by a third generation of the maggot in September. Soil examination on April 18, 1941, showed a maximum of 51 pupae per plant, with an average of 19.9, on a small planting of yellow turnip;a maximum of 14 per plant with an average of 4.9, on a small planting of broccoli; and a maximum of 11 per plant, with an average of 1.9, on a large planting of cabbage.

The first eggs of the cabbage maggot in the spring of 1941 were found on May 1, which is five days earlier than the average date for the past ten years. The normal field infestation was 85.72 percent commercial injury on the Golden Acre variety. One application of corrosive sublimate solution on May 3 gave 92.04 percent commercial protection and yielded 78 percent large and medium heads. Two applications of corrosive sublimate solution gave 96.67 percent commercial protection and yielded 83 percent large and medium heads. Calomel–talc powder containing 4 percent calomel applied at the rate of a teaspoonful around the stem of each plant on May 3 was also satisfactory, giving 100 percent commercial protection and yielding 75 percent large and medium heads.

In 1941 twelve varieties of cabbage were planted to determine their natural susceptibility to cabbage maggot injury. The results indicated that the early maturing varieties such as Golden Acre and the Savoy types were most susceptible, and the red varieties most resistant. Dry weather in the latter part of the growing season interfered with the records on head development, but Red Acre with 64.83 percent large and medium heads withstood the maggot injury and drought the best, while Golden Acre, which suffered the most maggot injury, gave the poorest yield with 7.69 percent marketable heads.

Susceptibility of Cabbage Varieties to Cabbage Maggot Injury, Waltham, Mass., 1941.

Very Susceptible (80 percent or more commercial injury). Golden Acre, Enkhuizen Glory.

Susceptible (65 to 80 percent commercial injury). Super Curled Savoy, Cornell Early Savoy.

Moderately Susceptible (40 to 65 percent commercial injury). Premium Flat Dutch, All Head Early, Danish Drumhead, Early Jersey Wakefield, Penn State Ballhead.

Slightly Resistant (25 to 40 percent commercial injury). Mammoth Red Rock, Red Drumhead, Red Acre.

Control of the Squash Vine Borer. (W. D. Whitcomb, Waltham.) The field infestation of the squash vine borer was 7.52 borers per vine, which is one of the greatest infestations ever recorded in the experimental field of Blue Hubbard squash at Waltham. Experimental sprays and dusts were applied July 7, 14, 21, and 28. The sprays were applied at 275 pounds pressure with a small power sprayer, and the dusts with a plunger type hand duster. The most effective treatments were a rotenone copper oxychloride sulfate dust, white oil emulsion 1 percent with nicotine sulfate 1-500 spray, and nicotine sulfate 1-250 spray. Rotenone talc dust containing 0.75 percent rotenone and a dust containing 20 percent cryolite with 5 percent metallic copper were moderately effective. Lead arsenate 3 pounds with fish oil 1 pint in 100 gallons of water as a spray was ineffective, this plot having an infestation only 12 percent less than the untreated check.

Yield records showed a significant increase in favor of the dusted plants, reflecting the beneficial action of a fungicide on the production of fruit. The plants receiving the rotenone copper oxychloride sulfate dust yielded 594 pounds more than the untreated check, an increase of 80 percent. As in previous experiments, there was no consistent direct correlation between yield and borer injury. The 1941 experiments also strengthened the theory that an infestation of 2 borers or less per vine before August 1 does not greatly reduce the yield.

Control of Onion Thrips. (A. I. Bourne.) The early spring was characterized by abnormally warm weather in April and was followed by more normal temperatures in May with very little rain during that period. This was followed by weather somewhat warmer than normal in June and rains which, although for the most part small in amount, were so frequent that field crops such as onions made an early start and grew rapidly.

Such weather conditions would normally favor the early appearance and rapid development of thrips but this was not the case in 1941. In the experimental plots of seed onions, thrips appeared late and developed slowly. There were practically no thrips on the plants throughout June, and by July 14 the average population per plant was only 10 thrips. Very high temperature in early July induced a rapid increase to the peak of 40 thrips per plant on July 21. Following a rainfall of nearly one-half inch on the 25th and a heavy downpour during the 28th (1.9 inches) the number of thrips was reduced to approximately 12 per

plant and remained at that low level until late August when the plants matured. No blast was observed.

Throughout the Valley, fields of both set and seed-grown onions were comparatively free from thrips. Results of tests of contact insecticides for thrips control were inconclusive because of the scarcity of the insects even on the unsprayed plants. Fixed nicotine with a resin residue spreader gave good initial control although its action was slower than that of nicotine sulfate. It was as effective alone as when used with a spreader. A rotenone extract with resin residue spreader had a high immediate effect and good residual action. Derris powder (4 percent rotenone) gave excellent kill within 24 hours, and reinfestation was slow. This was true regardless of the type of spreader used. Nicotine sulfate and soap caused the usual high mortality of thrips within a few hours after application but its residual effect was inferior to that of rotenone.

Predaceous insects were comparatively scarce during the early summer, but by mid-August syrphid flies and predaceous thrips had increased to considerable numbers and contributed very greatly to the rapid decline, in late August, of a very light but long-drawn-out attack of thrips. No evidence of fungus disease of thrips was observed.

The Spray Residue Problem. (A. I. Bourne.) The more liberal limits of tolerance established in the late summer of 1940 continued in effect for the shipping season of 1941. While the present limits are calculated to allow the growers greater latitude in their pest control program, the prolonged drought from late July until harvest and the uncertainty as to the permanency of the present limits made growers reluctant to enlarge their spray program, and for the most part very few changes were made. In the spray program recommended by the college for 1941 the only significant change was the suggestion of a 75-25 sulfur-lead arsenate dust as an alternate for the 2d cover spray.

Through the cooperation of the Control Service, analyses were made for lead and arsenic residue on samples of McIntosh collected from the sprayed plots at harvest. These analyses showed the amount of residue to be in all cases well below the present limits.

Fruit which had received the standard schedule recommended for the State showed residues of .031 grains of lead and .013 grains of arsenic per pound of fruit. Samples from the optional standard schedule in which no lime was used in the cover sprays gave .026 grains of lead and .009 grains of arsenic per pound. In the plots where wettable sulfur was used throughout the season, the lead residue ranged from .023 to .037 grains per pound and the arsenic residue from .005 to .015 grains. Lead arsenate was applied in the 2d cover spray (June 10) at 4 pounds per 100 gallons; 3 pounds in the 3d cover (July 2); and 2 pounds in the 4th cover (July 29). The fruit was picked September 15. While the total precipitation for July was nearly normal, approximately half of it occurred in one shower on the 28th. Records showed that during August and September little more than half the normal rainfall occurred, a deficiency of 3.67 inches. Fruit encountered unusually favorable conditions for the retention of spray deposits and normal weathering off could not take place.

Even under such a severe test as the past season offered, lead and arsenic residues were so far below present limits that there was a substantial margin of safety, which would indicate that if these limits are retained the growers will have more latitude for stiffening their spray schedule for late summer pests than they have enjoyed since spray residues became a problem of major importance.

Apple Maggot Control. (A. I. Bourne and W. D. Whitcomb.) Apple maggot proved to be of relatively minor importance in 1941, not only in Massachusetts but throughout most of the Northeastern States. In well-sprayed commercial

orchards the injury was negligible, and even in the smaller home orchards which received little attention the pest was not conspicuous.

This reduction is not believed to be due to any marked increase in energy on the part of the growers or to any improvement in the handling of dropped fruit or other precautionary measures. It is the general belief that adverse weather conditions and especially deficient rainfall at the period of normal emergence of the flies were the chief contributing factors.

In the emergence cages at Waltham the flies began to appear on June 19 which is the earliest date since the observations were started. Although the cages were operated in the same way as in the previous years, the emergence in the cultivated cage was greater than usual and that in the sod much smaller than usual. This condition is apparently correlated with the deficiency of soil moisture this year. The emergence record is as follows:

	In Sun — Light Soil	
	Cultivated	Sod
Degree of Emergence:		
First fly	June 19	June 24
25%	June 30	July 3
50%	July 7	July 9
75%	July 12	July 15
100%	August 7	July 27
Number of larvae in 1940	400	400
Number of flies emerged 1941	207	43
Percent emergence	51.75	10.75

Insecticides for the Control of European Corn Borer. (A. I. Bourne and W. D. Whitcomb.) The unseasonably warm weather throughout April promoted abnormally early pupation of the overwintering corn borer larvae. Seasonable weather in May allowed development to progress normally and resulted in a very early emergence of the spring brood of moths. On the other hand most of the growers planted corn at the usual time, with the result that considerable moth emergence took place before corn was above ground or at least when it was too small to be attractive for oviposition. In addition, during much of the time that the moths were present the temperatures at dusk were too low for moth activity. As a result the infestation by first generation larvae was negligible throughout the State. Growers harvested very clean corn even where no control measures were practiced, and in fields which were sprayed or dusted there was slight evidence of the borer.

In the experimental fields the plots sprayed with derris and Ultrawet showed 4 infested ears out of 660, 99.4 percent clean corn, 84.5 percent of which was grade 1 or 2; in other words, 84 percent of the total yield was marketable grade. A fixed-nicotine spray gave 97.1 percent clean corn, 84 percent of which was marketable. In the plots dusted with derris there were 4 infested ears in a total of 652, 99.4 percent clean corn, 90 percent of which was of marketable grade. Dual-fixed nicotine dust gave 98.8 percent clean ears, and 84 percent of the total yield was of marketable grade. The infested ears were so few that the grower made no effort to salvage them. The unsprayed check plots yielded a total of 682 ears, 48 of which were infested. In other words the infestation was so light that 92.9 percent of the yield was free from borers. In the entire field, regardless of treatment, only 83 ears out of 3,341 examined were infested. No attempt was made to spray late corn because of the scarcity of 2d brood larvae.

The infestation by the first generation of the European corn borer in the experimental planting at Waltham was so light that results of spray applications

were not significant. In the check plot there were 5 infested non-salable ears and 5 infested but salable ears in a yield of 203 ears. Hills sprayed individually with a mist nozzle showed 1 infested but salable ear in 219 ears, and the block sprayed with a spray gun from the border showed 2 infested salable and 2 infested non-salable ears out of 226. Powdered derris root 3 pounds and Ultrawet ½ pound in 100 gallons was used June 17, 24, 30, and July 7.

The second generation planting at Waltham was not sprayed because of the light infestation, and an examination on August 21 showed 15 infested ears or 1.34 percent in 1,118 ears examined.

On August 12 a part of this corn was treated for protection against the corn ear worm, by applying a standard lubricating oil–pyrethrum solution to the dried silk of the ears. No corn ear worm infestation developed but the treatment injured the ears by preventing pollination of the kernels in the terminal portion of the ear, indicating that this treatment is not satisfactory under all conditions. (See page 55.)

Potato Spraying Experiments. (A. I. Bourne) The weather conditions during spring and early summer furnished a very favorable start for potatoes and allowed them to keep this initial advantage. The plots were planted on May 9. The plants appeared promptly and growth was steady and rapid throughout the summer. The plants were slightly damaged by a light frost on the night of September 19-20 and were killed by a heavy frost on September 29-30. The crop was dug September 30 to October 2. In all of the plots sprayed with bordeaux the plants were alive, green, and thrifty until killed by frost.

Leafhoppers were very few and no outbreak occurred at any time during the season. Potato aphids became abundant in early July but were controlled by the addition of nicotine in the spray of July 16 and never threatened thereafter. Flea beetles were abundant throughout June and early July; the late July infestation was not so heavy. In the experimental plots 11 applications were made between June 11 and August 27. A new method of determining flea beetle injury was devised by which the number of feeding punctures was correlated with the amount of leaf growth. The plan was designed to show the amount of injury from week to week as well as the cumulative damage throughout the season. On this basis the amount of flea beetle feeding in the plots given a commercial spray of basic copper sulfate and sulfur was 103.1 feeding punctures per square inch of leaf surface; plots which received a basic copper arsenate–sulfur compound showed 45.1 feeding punctures per square inch of leaf surface; and the plot which received a neutral insoluble copper fungicide (double copper) showed 88.6 punctures per square inch.

In all the plots sprayed with home-made bordeaux mixture the damage from flea beetle feeding was very much less than that in the plots receiving commercial sprays. There was a slight advantage in favor of the low-calcium bordeaux, and the addition of calcium arsenate in every case furnished added protection.

The length of life of the plants in the different plots was in exact proportion to this index of beetle activity. The plants sprayed with basic copper sulfate and sulfur began to die early in August and by the end of the month practically all were dead. Plants in the plot given the basic copper arsenate–sulfur compound succumbed somewhat later. The plants given the neutral copper fungicide remained alive until mid-September. In all of the bordeaux-sprayed plots most of the plants were alive and green until the frosts of late September.

The summer was marked by a prolonged drought, and the lack of sufficient moisture interfered very seriously with the growth of the tubers and yields were proportionally reduced.

The yield records, however, showed a direct correlation with the amount of flea beetle injury. In the plots which received the commercial sprays, yields

of 308 to 346 bushels per acre were recorded, while plots in the same field which received bordeaux mixture yielded 420 bushels per acre. The plot which received the low-calcium bordeaux plus calcium arsenate gave the highest yield—474 bushes per acre, 76 percent of which was of number 1 grade.

Introduction of Parasites of Oriental Fruit Moth in Peach Orchards. (A. I. Bourne.) The work of rearing parasites of the oriental fruit moth was continued in 1941. By agreement with the Department of Entomology of the Connecticut Experiment Station, Mr. A. DeCaprio was again placed in charge of the collection and shipment of breeding material for both institutions. Parasitism was comparatively high in the New Jersey strawberry fields in 1941 and the season was early. Mr. DeCaprio, by benefit of his experience in past seasons, was able to locate superb fields for collection. Cool weather during the shipping period and rapid transit allowed the material to arrive at the laboratory in Amherst in very good condition.

The strawberry leaf roller larvae were very nearly full grown when collected so that very little migration took place after arrival in the laboratory. Emergence of the parasites was such that all the orders from growers were filled by June 30, and within the next few days a sufficient number of parasites emerged to duplicate all original orders, fill late orders, and in most cases duplicate these. The surplus material for distribution was made possible by the very proficient work of Mr. DeCaprio in collecting breeding material, the very accurate estimates of parasitism, and the improved technique in the laboratory. Fifty-eight growers in 9 counties received a total of 140 colonies. More than half the growers received their orders in half colonies to facilitate more uniform distribution in large orchards or for use in small, isolated blocks.

The warm weather, the unusually large number of hours of bright sunshine, and the few rainy days during the period of liberation offered very favorable weather conditions for the parasites.

Naphthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb and Wm. Garland, Waltham.) A complete series of experimental fumigations with a mixture of monochlor naphthalene oil 3 parts and commercial flake naphthalene 1 part indicated that the vaporization of $\frac{3}{4}$ to 1 ounce of the fumigant in 1,000 cubic feet constitutes a lethal atmosphere which will kill 80 percent or more red spiders if they are exposed for three hours. These results were obtained when the experiment was made at a constant temperature of 70° F. and a relative humidity of 50 percent, and also at 75° F. and 60 percent humidity. At the higher temperature and humidity the mortality was about 3 percent higher, especially at the shorter exposures.

A mortality of 30 to 40 percent resulted when the spiders were exposed for three hours to $\frac{1}{4}$ to $\frac{1}{2}$ ounce per 1,000 cubic feet, and an exposure of one or two hours to a lethal atmosphere killed only 15 to 25 percent. Potted carnations heavily infested with the common red spider mite supplied the experimental material, and the fumigant was vaporized at the rate of $\frac{1}{4}$ ounce per 1,000 cubic feet each hour for six hours. An infested plant was entered and removed each hour during the fumigation.

Control of the Common Red Spider on Greenhouse Plants. (W. D. Whitcomb, Wm. Garland, and W. E. Tomlinson, Jr., Waltham.) Life history studies of the red spider on different host plants at constant temperatures were continued. Most of the studies were on potted snapdragon and showed that the time required for development at 60°, 70° and 80° F. was approximately in a 3:2:1 ratio as follows:

	Average Number of Days at —		
	60° F.	70° F.	80° F.
From oviposition to hatching	14.48	7.71	3.81
From hatching to adult—male	15.70	9.46	5.35
female	19.17	11.00	6.25
From oviposition to adult—male	30.94	16.95	9.23
female	31.41	18.62	10.00

Oviposition records showed that although the female spiders laid about as many eggs at 60° F. as they laid at 70° and 80° F. in this experiment, they required about ten times as long to lay them.

Studies of red spider development on various host plants continue to indicate that there is some plant character which determines the rate of spider development, and studies to determine this are planned.

Spraying experiments with eleven advertised insecticides recommended for combating the red spider mites on roses were applied at weekly intervals in three series, using a greenhouse power sprayer at 275 pounds pressure. Of these, one material was very effective and outstanding; two were moderately effective and satisfactory; and eight were unsatisfactory. (See page 55.)

The most effective material is described as Technical Mannitan Monolaurate to which 1 percent rotenone and 1.8 and 2.6 percent other derris extractives have been added. When diluted to 1-400 this was the only spray material which reduced a natural infestation of 25 to 50 spiders per leaf to less than 5 live spiders per leaf, and consistently killed 90 percent or more of the spiders without injury to the plants. When diluted 1-600 this material was less effective but gave satisfactory control.

The other satisfactory materials, which combined rotenone and emulsified dispersing oils, reduced the infestation 60 to 80 percent and permitted 10-18 live spiders per leaf after treatment.

Unsatisfactory materials included rotenone combined with chlorinated heterocyclic hexylamine, powdered derris root and sulfonated castor oil, a commercial flour paste, monochlor naphthalene soap emulsion, a commercial preparation containing castor bean extract (ricin), and rotenone combined with hydrous aluminum oxide. Several of the rotenone sprays which gave unsatisfactory control of the red spider mite on roses gave excellent control of the same pest on potted carnations.

Three applications in March of a dinitro dust containing 1 percent dinitro-ortho-cyclo-hexylphenol killed 90 percent of the red spider mites and reduced an infestation from 25 to 2.4 live mites per leaf without injury to the foliage.

Biology and Control of the Apple Leaf Curling Midge. (W. D. Whitcomb, Waltham.) Although a strong northeast storm occurred on June 5 while the midge flies were still plentiful and might have been blown a considerable distance to the southwest, no new infestations outside of the previously known infested area were discovered or reported. However, this midge was found within the infested area in several orchards where it was not known to be present before 1941.

In the insectary the transformation to flies was 22.54 percent from maggots collected in June 1941, 45.41 percent from maggots collected in July and 11.11 percent from maggots collected in August.

In the observation orchard at Westford the infestation was very heavy during May and June but, because of the drought and absence of late summer growth even on watersprouts, it was below normal in late July and August. Records of 2117 bud tips on Baldwin trees examined at regular 3 and 4 day intervals between May 9 and September 12 showed that eggs were laid on 1712 or 80.87 percent of them. Oviposition was concentrated in three distinct periods when

eggs were found on every bud examined, namely May 27 to June 10, July 1 to 8, and July 22 to August 5. During the first two periods 100 tips were examined at each observation; but in the last period the number of tips available averaged less than 10, contrasted with 1940 when a large number of tips was available until about August 25. In 1941 the first eggs were found on May 9 which is 15 days earlier than in 1940.

Maturity of larvae and their emergence from rolled leaves was concentrated in three definite periods on June 17 to 24, July 8, and July 29. These periods generally correspond with the rainfall rather than with the development of generations which was extended and overlapped by abnormal weather conditions. The relative abundance of the midge throughout the summer is indicated by the number of larvae collected in 5 bands as follows: June 17, 2280; July 8, 244; and July 29, 790.

In a newly infested orchard at Waltham containing 96 trees of 7 varieties of approximate equal exposure to infestation, 893 infested buds were collected on June 12. The average number of infested tips per tree of each variety was: Delicious, 42.00; Rhode Island Greening, 8.75; Baldwin, 7.58; McIntosh, 4.54; Gravenstein, 3.16; Northern Spy, 0.33; and Wealthy, none. In this collection 63.29 percent of the infested tips were found on the Delicious trees. Another collection on July 9 yielded 532 infested tips on the same trees, making a reduction of 40.42 percent due to destruction of the maggots in the infested tips at the previous collection.

Similar collections from a nearby orchard where 396 infested tips were collected on 54 small trees showed an infestation of 11.94 tips per tree or 57.32 percent of the total on Starking; 6.00 per tree on Golden Delicious; and 3.58 per tree on Baldwin. In a block of young trees, 2 Milton trees had an average of 24.5 infested tips, indicating high susceptibility. At the same time no infested tips were found on 15 Macoun trees.

Continued experiments with naphthalene broadcasted at the rate of 2 pounds per 100 square feet showed that the treatment reduced the number of midge flies emerging from the soil and duff 79 percent at the first generation and 97 percent at the second generation.

Larvae and pupae in cocoons under the rough bark on the trunk of the trees were killed by experimental spraying with dormant sprays. Applications to the bark were made April 11 and July 1 using Elgetol (Standard Agricultural Chemical Company) 1 percent, Spra-Cream (B. G. Pratt Company) 3 percent actual oil, and Spra-Cream 3 percent plus DNOCHP (Dow Chemical Company) 15 ounces per 100 gallons. Cages enclosing 3 feet of the tree trunk were built around the sprayed trees. In these cages 84 flies of the first generation and 40 flies of the second generation were collected from the unsprayed tree, while only 2 flies were found in any of the cages on sprayed trees. Emergence of flies from mulch collected under trees where the above dormant sprays were applied at the rate of 2 gallons per 100 square feet indicated that considerable mortality of the midge resulted where Elgetol was applied but that the oil emulsion treatment was not effective.

Control of Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) In spite of unseasonably warm weather during the pre-blossom and blossom period of apples, the critical period of curculio activity did not occur until May 20-23 which was five to eight days after the petal-fall stage. This period was characterized by maximum temperatures above 85° F., but it was apparent that the suitable development of the fruit for feeding and oviposition was the most important attraction to the beetles.

Blocks of eight trees each were sprayed with lead arsenate 4 pounds, wettable

sulfur 4 pounds, fish oil 1 pint in 100 gallons of water when the fruit was 4/16, 5/16, and 6/16 of an inch in diameter, as determined by the measurement of 200 apples with calipers.

Variety	Diameter of Apples: Estimated (Inches)	Diameter of Apples: Actual Average (Inches)	Date Sprayed	Apples Stung (Percent)
Wealthy	4/16	4.10/16	May 20	18.72
	5/16	5.10/16	May 22	8.12
	6/16	5.94/16	May 23	18.70
McIntosh	4/16	3.84/16	May 20	11.53
	5/16	4.99/16	May 22	3.88
	6/16	5.92/16	May 23	5.42

These records, based on the examination of 57,835 apples, show least injury by the plum curculio to apples sprayed when they measured approximately 5/16 of an inch in diameter. This difference is the more significant since the "5/16" trees were located near a stone wall and fence row where much curculio injury has occurred in the past. In the Wealthy apples the curculio injury was 1 percent greater on dropped fruit than on picked fruit; but in McIntosh the dropped fruit showed 3 to 12 percent more injury.

Biology and Control of the Grape Plume Moth and Grape Cane Girdler. (W. D. Whitcomb and Wm. E. Tomlinson, Jr., Waltham)

Grape Plume Moth. A study of the parasitism of the grape plume moth yielded two new species (undetermined), but the total parasitism in the larvae collected was less than 1 percent.

The application of dormant sprays on April 10, just before the larvae hatched, showed that dinitro compounds are more effective than oil emulsion. In one experiment the addition of a DNOCHP compound at the rate of 15 ounces in 100 gallons increased the control from 74 to 86 percent over oil emulsion at the rate of 3 percent actual oil; and in another experiment the addition of DNOC (15 ounces-100 gallons) to 3 percent oil emulsion increased control from 60 to 82 percent. The best control was obtained with a commercial sodium dinitro cresylate 1 percent which gave 94 percent protection. When this material was used at ½ percent dilution the infestation was 12 percent or twice that following the use of the 1 percent dilution.

Grape Cane Girdler. The first activity of the grape cane girdler was observed on May 22 when the maximum temperature was 89° F. The average life of 26 individuals from egg deposition to adult in bagged canes in the vineyard was 60.8 days with most of the beetles emerging from August 15 to 25 but continuing until September 22.

In the vineyard, beetles were reared from 28 percent of the girdled canes under observation and this seemed to be a normal survival under the conditions.

Measurement of 100 canes showed that the average growth from May 22 to July 2 was approximately 1 inch per day, with Niagara and Fredonia making the most rapid growth and Delaware the least.

Sprays applied when the average cane growth was 4 inches or less prevented most girdling, but when the growth between sprays was about 8 inches the number of girdled canes was 8 to 15 percent greater than on the unsprayed vines. Cryolite at the rate of 3 pounds in 100 gallons was more satisfactory than lead arsenate, which caused some foliage injury when combined with sulfur or copper oxide in frequent applications.

Insects Concerned in the Dispersal of Dutch Elm Disease. (W. B. Becker.)

The Smaller European Elm Bark Beetle, Scolytus multistriatus Marsham. Elm logs in Alford, reported by the owner to have been cut just prior to April 1941, were found to contain only large larvae of *Scolytus multistriatus* at the end of September. No emergence holes could be found. If the time of cutting was given correctly, the size of the larvae present would suggest that one generation a year may be common in this region of the Berkshires. Logs of both American elm, *Ulmus americana* L., and slippery elm, *Ulmus fulva* Michx., were heavily infested. In an adjacent area, elm logs reported by the owner to have been cut at various times from the early spring through late fall of 1941 showed the presence of brood galleries in all stages of construction. Completed brood galleries containing large larvae, galleries with small larvae, and incomplete galleries with only eggs and active parent beetles were found.

The Native Elm Bark Beetle, Hylurgopinus rufipes (Eich.). At the end of September 1941, other elm logs in Alford which were reported by the owner to have been cut just prior to April 1941 contained larvae, pupae, and young adults of *H. rufipes* and many emergence holes. These logs were adjacent to those cut at the same time which were infested with *S. multistriatus*. The evidence suggests that in this vicinity *H. rufipes* beetles which develop from the first eggs laid in the spring may complete their development sooner than *S. multistriatus* beetles.

Insects Observed in the First Tree in Massachusetts Found to have Dutch Elm Disease. (W. B. Becker.) Numerous feeding or overwintering tunnels of *H. rufipes* were observed in the tree, especially near the base. Adult beetles were active in these tunnels in mid-September. Such tunnels, of course, are commonly encountered in live elm trees. No correlation was determined between the occurrence of these tunnels and the presence of the fungus, *Ceratostomella ulmi* (Schwarz) Buisman, in any part of the tree.

Scouting for Elm Bark Beetles. (W. B. Becker.) Brief scouting revealed the presence of *Scolytus multistriatus* at three locations new to this office: Concord, Alford, and Hancock, Mass.

At Alford, in the vicinity of the first tree in Massachusetts found to have Dutch elm disease, this beetle was abundant in elm logs on an area being cut over for cordwood. *Hylurgopinus rufipes* was also abundant in the vicinity of the diseased tree.

The Effects of Solar Heat on the Subcortical Development of the Native Elm Bark Beetle, Hylurgopinus rufipes (Eich.) at Amherst. (W. B. Becker.) Laboratory and field work on this problem was continued.

Insect Pests of Wood and Shade, Forest, and Ornamental Trees in Massachusetts. (W. B. Becker.) Three hundred and one inquiries were received about such insect pests. Eighty-four different kinds of insects were involved. Ants, powder post beetles, termites, spruce gall aphids, elm leaf beetles, and secondary tree-boring insects were received most frequently.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) Plants propagated vegetatively from Field Station rust-resistant strains of commercial hybrid snapdragons have been tested two summers under field conditions and in the greenhouse for two winters. These strains were highly resistant to rust disease; a wide range of flower colors was present, and growth and flowering habit were excellent. Many of these hybrids are still segregating for rust susceptibility and are heterozygous for flower color.

A few selections from seeded lines look promising as material for developing pure breeding forms for rust resistance and desirable flower colors. In earlier breeding work with Main's hybrids considerable difficulty was experienced in getting rust resistance bred into such selections and at the same time retaining desirable flower colors, growth habits, and blooming period in the same strains. It was anticipated that with the commercial variety hybrids this combination might be more readily developed into desirable pure-bred lines.

These hybrids are available now, provided florists are interested in growing snapdragons by propagating such strains from cuttings.

Cultural Requirements of Freesia. (Harold E. White, Waltham.) Records on the pre-curing or drying of freesia corms (5/8 to 3/4 inch size), for a period of 3 to 11 weeks prior to planting, show that by this treatment in 1939 corms lost from 3 to 24 percent of their weight; in 1940, 3 to 20 percent; and in 1941, 7 to 21 percent. Corms of Golden Daffodil (5/8 to 3/4 inch) in the 1940 treatment failed to sprout unless pre-cured for 3 weeks prior to planting. Corms of this variety received the same pre-curing treatment in 1941 but responded normally, which would indicate that, although the pre-curing treatments of the corms in 1940 overcame the growth inhibition factor, this same peculiarity was not present in the 1941 stock.

Loss in moisture content of freesia corms through pre-curing treatments has not been found to have any significant effect on the blooming or production characteristics of the corms. At a temperature of 48°-50° F., corms grown in benches flowered a week to ten days earlier than those grown in bulb pans. Early and later planted corms in bulb pans, shifted in November from a temperature of 50° F. to 60°F., flowered two weeks earlier on an average than those continued at the cooler temperature.

Results of tests in pre-curing freesia corms for periods of 2 to 11 weeks prior to forcing indicate that such treatments are not essential for successful forcing of freesias in the greenhouse. It is concluded that seasonal and cultural treatments given the freesia corms in the field are more likely to determine their forcing performance.

The use of well-rotted manure in soil mixtures for freesias has not had any harmful effect on the growth or flowering of the corms.

Foliage tip-burn of freesia plants may be caused by fumigants and by fluctuations in temperature, soil moisture, and humidity. Contrary to general opinion, freesias will take plenty of water when well rooted in properly drained soil and growing normally.

Elder's Giant White was observed to be a much slower growing type than Purity, Golden Wonder, or Golden Daffodil.

Soilless Culture of Florists' Crops. (Harold E. White, Waltham.) This system of plant culture has been conducted primarily as a demonstration for growers and to determine how much attention must be given to such a system to obtain crop production comparable to results from soil culture.

Carnation plants have responded equally well to some four to six nutrient formulas which have been tested. It is apparent, at least with carnations, that a considerable degree of adaptability to nutritional levels exists under soilless culture conditions, which is likewise true for plants grown in soil.

Root rot and stem diseases of carnations can be just as prevalent and destructive under gravel culture methods as in soil, particularly soon after the plants are set. Much of the danger lies in keeping the plants too wet rather than too dry. Tobacco and naphthalene fumigants can be used on carnations in gravel, following the same precautions necessary for successful fumigation of plants in soil.

New England growers have shown little inclination to grow flower crops in gravel, even on a trial basis. One grower, who last year was favorably impressed with the results from 350 square feet of soilless roses, has expanded to 2,500 square feet. At Waltham cinders, which for two years were used in growing roses, are now being used for the culture of carnations.

Liming Carnation Soils. (Harold E. White, Waltham.) Data for two years on the use of lime on carnation soils to determine the importance of soil acidity as related to plant growth and flower production show that carnations have a wide degree of adaptability to changes in soil acidity. The average acidity test of soil used for carnations was pH 5.6; the final acidity readings over a period of two years were 4.7 for unlimed and 6.4 for highly limed soils. While this test does not cover extreme ranges in acidity or alkalinity, it does pertain to normal variations of growers' soils as observed from soil testing records of five years at the Waltham Field Station.

There were no significant differences in flower production, number of split calyces, or vegetative plant growth between plants in unlimed soil and those in soil receiving applications of lime at the rate of 1 to 3 tons per acre.

Plants of the variety Ward were used in these tests and the same cultural treatments were given both years. Cultural and seasonal climatic conditions were of greater importance than soil treatments in their effect on crop production. The greater incidence of split calyces occurred between the months of January and April. During the season of 1940-41 plants produced only 2 percent more split calyces than during the previous season.

Field-grown plants produced four more flowers per square foot of bench area than greenhouse-grown plants. Since liming of soils had no perceptible effect on prevalence of root or stem rot diseases, the common practice of applying lime to correct or inhibit the spread of these soil organisms may be considered of little value for the purpose.

Disease Resistance and Heredity of Carnations. (Harold E. White, Waltham.) This work is merely getting under way. Thirty-five varieties have been assembled for study. The selfing of different varieties and experiments in germination of pollen are in progress.

In some preliminary breeding work in 1939–1940 a cross between the varieties Ward (pink) and Puritan (white) gave a progeny of 45.83 percent white flowers, 36.45 percent pink, 2 percent red, and 15.62 percent variegated flowers. The flower types were 8.24 percent singles, 56.70 percent commercial (normal) doubles, and 35.05 percent bursters or split calyx types. Short-calyx flowers were dominant over long or intermediate types. Broad-leaved characters of plants were dominant over narrow and medium leaf characters. These observations show, as was expected, that the commercial types of carnations are heterozygous for many of the plant characters to be studied in this project.

Coffee Chaff as a Soil Amendment. (Harold E. White, Waltham.) Inquiries are frequently received from manufacturing concerns as to the possible use in

greenhouse soils of certain waste organic by-products; when convenient, these materials are tested on the current-year crops at the Field Station.

Coffee chaff received from Wetmore and Company, Cambridge, Mass., was incorporated into carnation and snapdragon soils at the rate of two inches of the chaff to six inches of bench soil with no harmful effects to the plants. Also, it appeared to be quite suitable for use in potting soils and as a filler and conditioner in fertilizer mixtures.

According to the analyses of the Fertilizer Control Laboratory of the Experiment Station, one ton of coffee chaff has a trade valuation in terms of plant food of approximately $10 to $11.

Packet Seed Studies. (Clark L. Thayer.) For a sixth season the Department of Floriculture has cooperated with the Seed Laboratory in a test to determine the quality of flower seeds sold in retail seed stores, chain stores, schools, and other retail outlets. The seeds were tested for germination and performance under field conditions.

The test included 218 lots, representing 50 genera, packeted by 32 concerns, and obtained from 80 retail outlets. Records on germination showed 124 lots good; 55 lots, fair; 31 lots, poor; 8 lots, none. Records on performance showed 165 lots, satisfactory; 12 lots, fair; 41 lots, not satisfactory. Detailed results are reported in Control Series Bulletin 111.

Floriculture Soil Testing Service. (Harold E. White, Waltham.) The following tabulation shows the number of soils tested in 1941:

Roses	132
Carnations	508
Chrysanthemums	157
Gardenias	74
Snapdragons	106
Sweet peas	32
Miscellaneous	573
Total	1582

DEPARTMENT OF HOME ECONOMICS NUTRITION

Helen S. Mitchell in Charge

Vitamin Requirements of Older People. (H. S. Mitchell and A. W. Wertz.) Very little is known concerning vitamin requirements with advancing age. The favorable reports of the clinical application of vitamins, particularly thiamin, in geriatrics raise the question as to why such deficiencies exist. This study was undertaken with the hope of arriving at a better understanding of vitamin metabolism in older people. The project is partially sponsored by Standard Brands Incorporated.

Work now in progress concerns the correlation between cardiac changes, blood hemoglobin, red cell count, differential red cell count, and thiamin excreted in the urine, with the intake of pure thiamin versus the entire vitamin B complex. If possible the bisulfite-binding substances in the urine and pyruvic acid in the blood will be determined also.

Thiamin and Pyrimidine Studies on Older Subjects. (A. W. Wertz and H. S. Mitchell.) (*Proc. Soc. Exp. Biol. and Med.* 48: 259, 1941.) Four men and four women between the ages of 65 and 75 years were used as experimental subjects

in this study. The yeast fermentation method was used to measure the urinary excretions of thiamin and pyrimidine for each individual on graded levels of thiamin intake. There appears to be a sex difference in the excretion of thiamin which is not apparent in the excretion of pyrimidine. The response of people in this age group to increased thiamin intake is similar to that of younger people as far as excretion is concerned. Two out of eight subjects reported no subjective reaction to increased thiamin intake, two noted definite improvement in chronic constipation, four felt less fatigued or "peppier," two enjoyed improved appetites, and one noted an increased thirst.

Cause and Control of Nutritional Cataract. (H. S. Mitchell, G. M. Cook, and A. W. Wertz.) The experimental production of cataract in rats by feeding rations containing galactose has become a means of studying the effect of various dietary factors upon the lens. Since it has been well established by earlier work in this laboratory that a deficiency of protein aggravates cataract development and that a liberal supply delays it, the question naturally arose as to what factor in protein is responsible for the protective action. Anti-cataractogenic action of certain nitrogenous factors is being studied.

1. *The Influence of Certain Diamino and Dicarboxylic Amino Acids upon the Cataractogenic Action of Galactose.* (H. S. Mitchell and G. M. Cook.) Following the lead suggested by work reviewed in the 1940 Annual Report, certain individual amino acids are being investigated. It was reported that the enzymic hydrolysate of deaminized casein was somewhat more protective than the deaminized casein from which it was prepared. Of the fractions, the diamino-dicarboxylic acid fraction of the enzymic hydrolysate afforded as much protection as the whole hydrolysate, while the monoamino and proline and peptide fractions showed no protection. Since glutamic acid, histidine, arginine, and lysine are present in the protein hydrolysate fraction found to be most protective, these amino acids have been incorporated in a low-protein galactose ration in order to study any protective action. One of these amino acids has indicated slight protection. It and related compounds are being studied further.

2. *Time Factors in the Development of Galactose Cataract.* (G. M. Cook and H. S. Mitchell.) It has been observed in this and other laboratories that young rats are more susceptible to galactose injury than older rats. An experiment designed to investigate the question of this age factor is in progress. Rats from the same litter are started on experimental rations at fortnightly intervals. The one started later required a longer time for lenticular injuries to become evident. The complete data are not yet available.

The injury due to galactose seems to persist in rats after they have been transferred to rations containing none of this sugar. The blood sugar returns to normal within a few hours after the ration change is made. The apparent lag in the galactose injury must be due to slow diffusion from eye fluids. The extent of this lag is being investigated by discontinuing the galactose ration at four-day intervals in a series of rats from the same litter.

The Nutritive Value of the Iron of Cocoa and Iron-Fortified Cocoa Mixtures. (F. Kinder and H. S. Mitchell, with the cooperation of W. S. Mueller of Dairy Industry.) Inasmuch as iron is precipitated in the presence of tannic acid and from 2 to 15 percent of tannic acid is present in commercial cocoa, there arises the question of the availability of the iron in cocoa and foods associated with it. The current use of chocolate milk and chocolate-flavored foods makes the problem one of practical interest.

The nutritive value of the iron of cocoa and iron-fortified cocoa was determined by biological procedure. The iron of cocoa was not so well utilized (approx-

imately two thirds as much hemoglobin regenerated) as an equivalent amount of ferric chloride. The addition of pure tannic acid did not decrease the utilization of iron added to a milk ration. Iron added to cocoa was completely available, indicating that the factor which limited the nutritive value of the iron of cocoa had no influence on added iron. Both cocoa and tannic acid retarded the growth of rats, but the effect of the tannic acid was less severe than that of the cocoa.

It may be concluded from this study on rats that cocoa may be fortified successfully with iron. However, the indiscriminate use of chocolate or cocoa milks is not recommended because of the yet unexplained effect of cocoa on growth and intestinal function.

Effect of Adding Cocoa to Cow's Milk on Utilization of Calcium and Phosphorus. (M. R. Cooney, with the cooperation of W. S. Mueller of Dairy Industry.) Interference with the solubility of calcium and phosphorus is a matter of concern when cocoa is added to milk, since cocoa contains oxalic acid, which if present in large enough amounts may prevent the absorption of calcium by the formation of insoluble calcium oxalate.

Accepted standard biologic and chemical procedures are being used to determine whether or not the utilization of calcium and phosphorus is impaired by the addition of cocoa to milk. Results are not yet available.

The Influence of College Life on the Physical Status and Food Habits of Massachusetts State College Women Students. (M. S. Gutowska and E. B. Ellms, Department of Student Health.) In order to determine the physical and nutritional status of the women students, a study is being conducted of the basal metabolic rate, the creatine output, and the urine and blood picture of the freshman women students. A general medical examination is the starting point of this study. The dietary habits of the girls as well as their daily intake of calories and protein are recorded through individual computation. Sixty cases have been investigated thus far.

These determinations provide material for an evaluation of the physical status of the women students, and it is planned to continue them for the next three college years.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

C. R. Fellers in Charge

Cranberry Research. (C. R. Fellers and A. S. Levine.) About 25 percent of the cranberry crop is now used for canned or other manufactured products. Cranberry juice and cranberry sauce were shown to be definitely bacteriostatic for many bacteria of the food-poisoning group. There were also indications that these foods had a marked cleansing action in the mouth.

Cranberries contain small amounts of riboflavin, pantothenic acid, and thiamin not previously reported.

In sauce manufacture, the extraction of the berries with water at 185°-195° F. for 20-25 minutes resulted in increased yields of sauce over the usual short-time extraction at the boiling point. The pectin is conserved and a sauce of improved quality results.

A new concentrated sirup was prepared by first cold-pressing the juice, treating with Pectinol to revive pectin, filtering, and concentrating in vacuum. This sirup serves as a beverage base or as a pharmaceutical vehicle.

Apple Products Including Apple Juice. (W. B. Esselen, Jr., A. S. Levine, C. R. Fellers, C. C. Strachan.) In view of the increasing interest in bottled and canned

apple juice, further studies have been made on this product. All of the commonly used methods of clarification were compared in order to determine which would give the best-flavored juice. Flash pasteurizing the apple juice at 185° to 190° F. followed by flash cooling with subsequent filtering, using 2½ pounds filter-aid per 100 gallons juice, was definitely superior to the gelatin–tannin and pectinase enzyme methods. The bentonite method was preferable to the latter two methods but inferior to the first-described method from the standpoint of optimum flavor quality.

Flash pasteurization at 175° to 180° F. and filling hot into the containers, followed by sealing and rapid cooling is recommended.

In Massachusetts the McIntosh is the most important commercial apple crop. Unfortunately the juice of the McIntosh has a rather insipid flavor and must be blended with other varieties to make a palatable apple juice. Tests were made to determine the maximum amount of McIntosh juice that could be blended with Baldwin or Delicious juice to yield a satisfactory commercial product. It was found that blends containing up to 60 percent of McIntosh juice yielded a pleasing product. In such blends it is not recommended that over 25 percent Delicious apples be used owing to their strong aromatic flavor.

Apple juice, fresh or canned, contains little vitamin C regardless of the vitamin content of the apple. Fresh apple juice actually destroyed added vitamin C. However, after inactivation of the oxidizing enzymes by heat treatment, the ascorbic acid remained biologically active in the canned or bottled juice. Ascorbic acid is present in apple juice only in the reversibly oxidized form. It is entirely feasible to fortify processed apple juice with crystalline ascorbic acid at the rate of 20 mgm. or more per 100 ml. of juice. The crystals are first dissolved in the deaerated juice which is then flash-pasteurized and canned or bottled without delay. The containers are preferably sealed under vacuum or by displacement with an inert gas such as nitrogen. Juice fortified by this method retains about 90 percent of the added vitamin C after 3 months.

Fruit Jellies and Jams. (A. S. Levine, S. G. Davis, and C. R. Fellers.) The beach plum (*Prunus maritima*) has been used locally for jelly making. Representative samples of the fruits from Cape Cod were collected and some were frozen. Studies are in progress on improved methods of utilizing this fruit in jellies and other products, as well as on composition and nutritive value. Beach plums do not make firm jellies without the addition of pectin, but the added pectin seems to injure the flavor. On the other hand, beach plums make excellent jam without the use of added pectin. The aroma and pleasing astringency are superior to those found in the jelly. It would appear, therefore, that more attention should be centered on the jam and less on the jelly.

The Japanese quince, *Chaenomeles japonica*, a well-known ornamental shrub, produces a considerable quantity of fruits of very pleasing aromatic odor. Attempts were made to utilize these fruits in jelly manufacture. The malic acid content is 5 percent and while considerable pectin is present, the pure jelly lacks character and is excessively acid. Unfortunately, the perfume-like aroma of the fresh fruit is lost in the jelly and in the heat-extracted juice.

Vitamin C Content of Catsup. (W. B. Esselen, Jr., and H. Fran.) A survey has been made to determine the vitamin C content of tomato catsup. Samples for analysis were obtained from the local markets and through the courtesy of several catsup packers. The vitamin C content of nine different brands of catsup varied from 0.05 to 0.12 mgm. per gram or from 28.3 to 68.0 I. U. per ounce. This variation in the vitamin C content of catsup is probably due to its air content, possible copper contamination from equipment, storage temperature, and length of time in storage.

Change in Oxidation-Reduction Potential in Packaged Fruit Juice. (W. B. Esselen, Jr.) A preliminary study has been made on changes in oxidation-reduction potential in canned and bottled fruit juice. In glass-packed orange juice, there was no correlation between the oxidation-reduction potential and flavor changes which took place immediately after packing. The oxidation-reduction potential of apple juice was much lower in plain tin cans than in enamel-lined cans or bottles. Any beneficial effect that the low oxidation-reduction potential of the apple juice in plain tin cans might have in preventing deleterious oxidative changes was offset by an undesirable metallic flavor of the juice.

Glass Container Research. (C. R. Fellers, W. B. Esselen, Jr., W. H. Fitzpatrick, E. L. Moore and J. J. Powers.) Because of the scarcity of tin plate, there has been a marked renewal of interest in glass containers for food packing. Extensive studies have been made on the problems of packing fruits and fruit juices in glass packages. Earlier work on the efficacy of ascorbic acids in preventing discoloration of glass-packed fruits has been confirmed. The use of 1 or 2 one-grain tablets of d-isoascorbic acid or d-glucoascorbic acid in pint or quart jars of canned fruit or vegetables effectively prevented discoloration and off-flavor due to oxidation.

After sealing, commercially packed foods in glass containers lose but little vitamin A and C (*Food Research* 6: 135-141, 1941). Further studies have shown that the total decrease in ascorbic acid is approximately proportional to the enclosed oxygen. Thus, among the important factors influencing ascorbic acid retention are: (1) volume of headspace, (2) degree of vacuum, (3) amount of dissolved and tissue oxygen. Similarly, these same factors may also affect color, flavor, and other characteristics. Modern commercial packaging methods seek to eliminate oxygen from canned foods. This study shows the effect of varying oxygen content on ascorbic acid retention. In fruits and vegetables with high ascorbic acid content (citrus fruits, strawberries, broccoli, etc.), only a small percentage of the ascorbic acid is lost in canning. However, in those initially low in ascorbic acid (pears, peaches, apple juice, plums, carrots, beets, etc.), a substantial percentage, or all, of the ascorbic acid may be lost through reaction with oxygen. Color and flavor of the latter fruits are also adversely affected. High storage temperatures and exposure to light accelerate the ascorbic acid—oxygen reaction in glass-packed foods, but the final total loss of ascorbic acid is unaffected by these factors.

The No. 10 size (105-ounce) glass jar was used experimentally for frozen-packs of strawberries, raspberries, and peaches, packed with and without vacuumization. Results show that vacuum sealing is generally preferable and that this large glass package is very satisfactory for frozen fruits. As in the case of canned fruits, the use of ascorbic acid in small amounts resulted in decreased surface discoloration due to oxidative changes.

Marine Products Research. (C. R. Fellers and J. Lubitz.) Cooperative with Poultry Department. New England poultrymen are constantly searching for new low-cost feeds. Recent developments in canning Atlantic coast crabs have made available considerable quantities of crab meal. This product contains about 34 percent protein, 40 percent ash (mainly calcium), and 2-4 percent fat. The riboflavin content is 3-4 gammas per gram. Pantothenic acid, thiamin, and vitamin K are also present. The meal is an especially good source of calcium, magnesium, iodine, manganese, iron, and copper.

In feeding experiments with rats 85 percent of the nitrogen was available, the balance being present largely as unavailable chitin. Upon hydrolysis chitin yields glucosamine, which proved to be entirely unavailable to rats and chicks

as a source of nitrogen. The biological value of crab protein was approximately the same as that of good grade fish meal. Pigmentation in chicks was slightly increased by feeding crab meal as compared with fish meal. In the New England Conference Chick Starter ration the replacement of fish meal by crab meal on either an equal-weight or equal-protein basis gave results highly complimentary to crab meal. Crab meal sells at considerably lower prices than fish meal; it would seem to be a very satisfactory ingredient of poultry rations.

Dextrose Investigations. (C. R. Fellers, A. S. Levine, and L. Tarkow.) Studies have been concluded on the relative bacteriostatic and mycostatic properties of sucrose, dextrose, and mixtures of the two sugars. Dextrose kills and prevents the growth of bacteria, yeasts, and molds at lower concentrations than does sucrose. That is, dextrose sirups (above 30 per cent) are far less liable to ferment or mold than similar sucrose sirups. The use of dextrose in canned foods, in carbonated beverages, and in soda-fountain crushed fruits and sirups is rapidly increasing. The smaller molecule and the greater osmotic pressure exerted by dextrose in solution are believed to contribute to the greater preserving value of this sugar.

Red Squill Research. (A. S. Levine, C. R. Fellers, and J. Lubitz.) Improved methods for rat extermination are now more important than ever before in reducing the nation's loss by waste.

Red squill was found to be harmless for chickens and rabbits. Guinea pigs are more susceptible than rats to red squill poison. Some popular flavors have been found to be of little value as rat lures. Among these are meat, cheese, anise, caraway, cinnamon, and peppermint flavors. The composition of common baits used as carriers for the squill had little effect on the toxicity of the poison to albino rats.

On account of the war there is now no importation of red squill, and most stocks of red squill still in this country are of low toxicity to rats. Through concentration and subsequent bioassay studies an attempt is being made to increase the toxicity of the present supply.

Three papers have been published on red squill research.

Preservative Values of Organic Acids. (A. S. Levine, R. E. Morse, and M. G. O'Connor.) The addition of small amounts of acetic acid (vinegar) does much to improve the keeping qualities of soda fountain sirups and fruit juices with no impairment of flavors. The addition of only 0.3 percent acetic acid inhibited both yeast and mold growth in strawberry and raspberry sirups. This is especially favorable when compared with the high amounts of citric and lactic acids required for complete inhibition. More than 6 percent citric acid or 5 percent lactic acid was necessary to inhibit yeast growth in these sirups. Four percent lactic acid prevented mold growth but the mold, *Aspergillus niger*, grew in sirups containing over 7 percent citric acid.

Benzoic acid and especially sodium benzoate are still used extensively for the suppression of yeasts in the preservation of fruit juices and sirups. A study is now in progress to determine the effect upon yeasts when definite concentrations of sucrose, dextrose, alcohol, and sodium chloride are used in conjunction with the benzoates. In the preservation of apple juice as much benzoate was required to preserve the clarified as was needed for the unclarified or cloudy juice.

DEPARTMENT OF HORTICULTURE

R. A. Van Meter in Charge

Propagation of Hemlock. (Harold S. Tiffany, Waltham.)

Canadian Hemlock, Tsuga canadensis. Cuttings of one-year wood were taken from hedge trees approximately fifteen years old, in three series at five-week intervals: December 9–14, 1940; January 13–18, and February 17–21, 1941. The rooting medium was one-third peat and two-thirds sand, in open benches under cheesecloth tents and whitewashed glass. Cuttings were kept fairly moist. All treatments were run at constant temperatures of 65°, 70°, and 75° F. (maintained by electric cable), as well as in an unheated bench where the temperature averaged about 60°. Each lot consisted of six cuttings.

Immersion treatments consisted of honey, 25 and 50 percent solutiens for 24 hours; indolebutyric acid in the form of Hormodin A, at concentrations of 30, 45, 60, 75, 90 BTI units for 24 hours (with additional treatments at certain temperatures); indolebutyric, indoleacetic, and naphthaleneacetic acids, each at concentrations of 7½, 10, 12½, 15, 20, 30, 40, and 50 mg. 100 c. c. water for 24 hours (with additional tests for 16 and 40 hours); Roche 202, at 50, 100, 200 unit solutions for 24 hours. Powder treatments consisted of Formula No. 66 and Hormodin Powders Nos. 2 and 3. An untreated or check lot was included.

Untreated lots rooted little or not at all: at 60° F., 16 percent; at 65°, 33 percent; at 70°, 16 percent; and at 75°, none. Rooted cuttings of successful lots could have been potted at ten to twelve weeks.

Outstandingly rapid rooting, as compared with other treatments, was shown by Hormodin A, 30 BTI units for 24 hours at 75° F. This reaction checked similar findings of the previous season (Hormodin A, 45 BTI units for 24 hours). See photograph page 56.

Cuttings from Series I, taken in early December, gave much higher percentages of rooting than those of Series II or III. In the previous year mid-December cuttings did not root as successfully as those taken in mid-January. This variability can be at least partially explained by the early low temperature and snow fall of November 1940 which brought the cuttings to a condition for satisfactory rooting much earlier than was the case in the preceding year when such conditions did not materialize until January.

Of the thirty-one treatments which gave 100 percent rooting, the most consistently successful was indolebutyric acid 7½ mg./100 c. c. for 24 hours. The finest normal root systems were developed with this treatment at 65° F. (see photograph, page 56), with good rooting at 70° and 60°. Of economic significance is the fact that this treatment gave 83 percent good rooting in the unheated bench at an average temperature of 60° (widest fluctuations in the bench temperature were 57° and 63°). Consistency of the treatment at 65° is further shown by 100 percent rooting from 7½ mg. upward through 40 mg., although as the concentration increased the roots were shorter and some injury was apparent.

Hormodin A trials were consistently good with percentages of 100 on half the lots. Best-developed root systems were from 90 BTI units, 24 hours at 65° F. As would be expected, lower concentrations did best at higher temperatures and vice versa. This was shown particularly well by the best 100 percent rootings in the Hormodin A, 24-hour trials: 30 BTI at 75°, 60 BTI at 70°, 90 BTI at 65° and 60° F.

Cuttings treated with indoleacetic acid gave 100 percent rooting at 60° and 65° F. with concentrations up to 10 mg./100 c. c. In no instance did the condition of the roots excel or equal the condition of those treated with indolebutyric acid.

All naphthaleneacetic acid treatments gave indication of injury by basal burn

and proliferation of roots. Roche 202 treatments gave variable results—from 0 to 100 percent rooting. As in the case of most treatments, best rooting was at 65° F.

Hormodin Powder No. 2 brought 83 percent rooting at 70° F., but fell to 66 percent at 65°. Hormodin Powder No. 3 gave best rooting at 65°—100 percent. Root development with powder treatments was much inferior to that produced by immersion treatments of indolebutyric acid. The results with Hormodin Powder No. 3 were generally paralleled by Formula No. 66.

Tsuga canadensis vars. *pendula* and *minima*. Results of treatments suggest these varieties propagate readily. The records approximately parallel those for *T. canadensis*.

Tsuga canadensis var. *Beaujean*. Preliminary tests of twelve lots suggest that this variety does not propagate so readily as those mentioned above.

Generally, indolebutyric acid has shown definitely superior results to other treatments in these trials and at low concentrations. A constant temperaure of 65° F. appears optimum throughout the trials, with the exception of Hermodin A at 30 BTI at 75°. Cuttings rooted best when taken soon after the first protracted cold weather of the season.

Tests will be continued in 1941–42 with indolebutyric acid in various forms at minimum concentrations and optimum temperatures.

Propagation of Mountain Laurel. (Harold S. Tiffany, Waltham.) Preliminary trials in 1940 gave indication of a low percentage of rooting from hardwood cuttings of mountain laurel, *Kalmia latifolia*, taken in mid-January. Treatment with indolebutyric acid in the form of Hormodin A at 60 BTI units for 16 hours gave 20 percent rooting, while fairly high concentration of the salts gave only 10 percent. These roots developed in a sand medium; no roots developed in a medium half sand and half peat, or in peat alone.

Since successful propagation of the best white and deepest pink variations of mountain laurel would be of decided value, a program of winter propagation trials was carried out during 1940–41. Three series of cuttings were taken: December 19–26, 1940; January 30–February 6 and March 13–20, 1941. Thirty-eight treatments (plus other varied trials) in lots of six cuttings each for each series were duplicated at constant temperatures of 65°, 70°, and 75° F., and in an unheated bed averaging 60°. These were as follows: honey, 25 and 50 percent solutions; Formula No. 66 and Hormodin No. 3; Hormodin A at 45, 60, 75, 90, 120, 150 BTI solutions; indolebutyric, indoleacetic, naphthaleneacetic acid salt solutions at concentrations of 10 mg./100 c. c. through 80 mg./100 c. c. (10 unit progression); Roche 202 at unit strengths of 50, 100, 200, 300; and an untreated lot.

While rooting percentages of the previous season's tests were perhaps slightly bettered (33 percent), it appears from these results that the propagation of mountain laurel from hardwood cuttings may not be feasible.

The twenty-eight plants rooted did not continue root development after transfer to pots, seeming to hold only growth that had been made in the rooting medium. The cuttings rooted in 1940 also exhibit an equal lack of normal vitality.

Propagation of Lilac. (Harold S. Tiffany, Waltham.) The time of taking cuttings of the common lilac, *Syringa vulgaris* var. *Andenken an Ludwig Spaeth*, has been varied from May 28 to July 1. In no instance have rooting percentages been as high as for those taken in late May at the time the flowers are about half way into bloom. At this time the new growth is about 6 to 8 inches long, making for good-sized plants when rooted. Rooting percentages of the 1200 cuttings taken for test June 10, 1941, about two weeks after the optimum time, fell off

from 30 to 40 percent. Optimum temperature of the medium, one-third peat and two-thirds sand, was found to be about 70° F. Hormodin A, 40 BTI units for 24 hours, and Formula No. 66 each gave 95 percent good normal rooting.

Propagation of Juniperus virginiana var. glauca. (Harold S. Tiffany, Waltham.) Several varietal forms of *Juniperus virginiana* are propagated commercially by grafting to understocks of this species, since no satisfactory percentage of rooting has been obtained from cuttings. The variety *glauca* is one of these.

Preliminary trials in 1940 of wood of the current season and of two-year wood gave high rooting percentages on the one-year wood and very low percentages of rooting on the two-year wood. Both sand and half sand, half peat appeared satisfactory media, although cuttings in the sand–peat rooted satisfactorily in 11 weeks, while those in the sand consistently required 14 weeks.

A series of cuttings, twenty to each treatment, taken in late January 1941, were put in sand–peat in open unheated benches at a temperature averaging 62°. Thirty-four treatments with root-inducing substances were made for 16, 24, and 40 hour immersions.

Indications show successful rooting confined to indolebutyric acid treatments with a range of rooting percentages up to 100. Untreated cuttings gave no indication of rooting. A higher temperature of the rooting medium appears to be necessary for best results.

Factors Increasing the Rapidity of Growth of Nursery Stock. (Harold S. Tiffany, Waltham.) To determine best cultural practices for rapid quality growth of lining out stock, plots of various plant materials have been laid out from 1939 through 1941. These include plantings of *Tsuga caroliniana* and *canadensis*, *Thuja occidentalis* var. *globosa*, and *Syringa vulgaris* var. *Souvenir de Ludwig Spaeth*.

A series of fertilizer treatments was applied in duplicate, in 1940 and 1941, to fourteen plots of *Tsuga caroliniana*. Treatments were based on 5-8-7 (one third ton per acre) as a balanced fertilizer adequate in amount for the needs of young evergreen trees. One-half the nitrogen was supplied by nitrate of soda and one-half by sulfate of ammonia. Phosphorus was supplied by superphosphate, and potash by muriate of potash. Manure and peat moss represent two other treatments.

Growth measurements in inches for each of the years 1940 and 1941 were secured from plots treated with manure (15 cords per acre) and peat moss (annual application of 2 inches hoed into the soil).

While other treatments also show measurements exceeding those of the untreated plots, further results are needed before conclusions can be drawn.

Study of Herbaceous Perennial Material. (Harold S. Tiffany, Waltham.) Records of the 1941 season have been included with material previously obtained, giving the average time and duration of bloom, height, and color of the better and enduring garden perennials. Averages for a period of five years are now available for most of the plants.

Additions to the peony collection, chosen as representative of the best of their types from a study made by the University of Illinois and the American Peony Society, are as follows: Single—Catherine Parry, Departing Sun, Harriet Olney, Le Jour, Marguerite Dessert, Mellin Knight, Mischief, Shirley Walker; Japanese—Antwerpen, Cathedral, Fuyajo, Hakodate, Kukenu-Jishi, Margaret Atwood, Mikado, Some-ganoko, Surugu.

Hardiness Trials of Clematis Varieties. (Harold S. Tiffany, Waltham.) A limited number of three-year plants was set in the nursery, from pots, in the

spring of 1940 and given a severe test the following winter without the benefit of winter protection.

The only 100 percent survivors after a winter during which a lasting blanket of snow offered good protection, were the varieties Mme. Edouard Andre, Elsa Spath, and Duchess of Edinburgh. Over 75 percent of *Comtesse de Bouchaud* lived; 66 percent of *Henryi*; and 50 percent of *Romona* and *montana* var. *rubens*. The species *ascotiensis*, *crispa*, *tangutica* var. *obtusiuscula*, and the varieties Belle of Woking, Gipsy Queen, Mrs. Cholmondeley, Nelly Moser, Ville de Lyon, and Ville de Paris were entirely winterkilled.

While the number of plants was insufficient for a thorough test, and although the test represents but a single winter, the hardiness of the plants of Mme. Edouard Andre, Elsa Spath, and Duchess of Edinburgh is promising.

Powdery Mildew on Garden Phlox. (Harold S. Tiffany, Waltham.) A spray control program of Bordeaux mixture 1-1-50, Hammond's Copper Solution 1-150, Basi-Cop 1-50, and Wettable Sulfur 2½-50 was applied to plantings of *Phlox paniculata* from May to the time of flowering. Applications were made at intervals of 7 to 10 days.

Hammond's Copper Solution, with no residue, was again superior in both control and appearance to Bordeaux Mixture, which left some residue on the plants. Wettable sulfur gave better results than did Basi-Cop.

Factors Influencing the Hardiness of Evergreens. (Harold S. Tiffany, Waltham.) Records of terminal growth averages on *Taxus baccata repandens* after the first season of cultural treatments showed a definite correlation of growth with treatment. Sod with no cultivation afforded fairly normal growth, yet the plants lost much of this growth by the next spring. Cultivation with no fertilizer gave a normal amount of growth, and these plants suffered least from winter injury. The spring application of nitrate of soda at the rate of 300 pounds per acre gave the most growth, yet the plants were not injured comparably. As expected, greatest winter injury came from manure, 15 tons per acre applied in May and in August.

Winter injury is calculated by (a) the number of terminals entirely winterkilled, (b) terminals killed approximately two inches from tip down, (c) tip injury to the bud with approximately ten needles killed, and (d) number of retarded terminals after growth has started. After trying several methods of measuring winter injury, this means appears to hold fairly constant.

In 1941 additional fertilizer was given with the late August application of manure for still further contrasts. A cover crop of annual rye grass was planted in August on the nitrate of soda plot to check growth early and encourage hardening after a rapid early growth.

The dry 1941 season consistently lessened growth averages by approximately 25 percent. An exception to this was plants of *Taxus canadensis stricta*, which showed more average growth than in the previous season in all plots. Explanation may be that the plants had not become fully established at the end of the first season of treatments, or that they withstand drought better than either *Taxus baccata repandens* or *Taxus cuspidata*.

Propagation of Mugho Pine. (Harold S. Tiffany, Waltham.) A series of cuttings of Mugho pine, *Pinus mugo* var. *Mughus*, was given preliminary tests in 1939-40, and the work for 1941 was based on the results of these tests.

Lots of five cuttings each of one-year wood taken in January were placed in open benches, in a rooting medium of one-third peat and two-thirds sand, with temperatures averaging 65° and 62° F. Dip treatments consisted of Formula No. 66 and Hormodin No. 3; immersion treatments, of honey 25 and 50 percent

solutions, Hormodin A at 30, 45, 60, 75 BTI units, indolebutyric, indoleacetic, and naphthaleneacetic acids at concentrations of 10, 15, 20, 25, 30, 35, 40, 45, 50, and 60 mg./100 c. c., Roche No. 202 at unit concentrations of 25, 50, 75, 100, 125, 150, 175, 200; and an untreated lot. Each immersion treatment was continued for 16, 24, and 40 hours.

A series of fifteen cuttings to the lot was taken in February and run in sand and sand–peat at a constant temperature of 65° F. Treatments were Hormodin A at 90, 105, and 120 BTI units, with additional test treatments of indolebutyric acid. Results were slightly better from the sand–peat medium than from the sand, and from a higher temperature of the rooting medium. Highest rooting percentage was 80 with indolebutyric acid at 40 mg./100 c. c. for 24 hours at 65° F. in sand–peat. Immersion treatments for 24 hours with Hormodin A at 90 BTI units (in sand) and at 120 BTI units (in sand–peat) gave 66 percent rooting; and at 90 BTI units (in sand–peat) 65 percent rooting at 60° F. In the untreated lots a single 13 percent rooting occurred at 65° F. in the sand–peat medium. Rooting from other lots was negligible.

DEPARTMENT OF OLERICULTURE

Grant B. Snyder in Charge

Variety Studies. (W. H. Lachman and G. B. Snyder.) These studies are conducted each year to ascertain the adaptability and general usefulness of the newer introductions in comparison with the standard vegetable varieties. The weather conditions at Amherst during the summer of 1941 were very near to the average for the last 50 years and were ideal for proper growth and development.

Especially noteworthy was the new "Summer Pascal" celery which produced a medium large plant weighing a little over two pounds and measuring about 20 inches in height. This variety produced a crisp, succulent stalk with an excellent nutlike flavor.

There were 62 strains and varieties of tomatoes included in the trials. Particularly outstanding were "Stokesdale," an early mid-season variety which yielded well and had good shape and size, and "Rutgers," a late, high-yielding, very attractive tomato which is especially valuable for canning. The varieties "Victor" and "Bounty" which are early varieties proved a little disappointing because of poor fruit color and sparseness of foliage. "Pan American," a new introduction of the U. S. D. A., is reported to be highly resistant to fusarium wilt. This variety has excellent foliage, but from the experience gained by limited trial, large plantings are not suggested because of only a moderate yield and variable fruit shape and size when grown either pruned and trained or unpruned and untrained.

During the summer, eight varieties of tomatoes were tested for vitamin C, with the following results:

Variety and Source	Ascorbic Acid (mg. per gram of tomato)
Bounty—N D. Agr. Expt. Sta.	.15
Early Rutgers—N. J. Agr. Expt. Sta.	.20
Gradwell—Scott	.21
Marglobe—Landreth	.17
Ohio Red—Ohio Agr. Expt. Sta.	.16
Pan American—U. S. Dept. Agr.	.21
Victor—Harris	.17
Waltham Forcing—Waltham Field Station	.23

Also important among the newer vegetables was the "Yankee Hybrid" summer squash. This variety is from three to seven days earlier than standard varieties. It has a straight neck, good quality, uniformity, and gives an exceptionally high yield over a long season. The "Delicious" and "Golden Delicious" varieties of winter squash were outstanding in quality and store moderately well.

Shape Index Studies of Tomatoes. (W. H. Lachman.) Five years ago a quantity of seed was obtained of eight varieties of tomatoes that displayed major differences in the shape of their fruits. Each year small plantings have been made from the original stocks of seed to determine the effect of the various weather conditions in modifying the shape of tomato fruits. While considerable data have been collected, it is felt that more information is necessary before the results are summarized.

Tomato Breeding. (W. H. Lachman and G. B. Snyder.) The tomato breeding project has been confined to the problem of incorporating the uniform ripening gene into otherwise desirable tomato varieties. The uniform ripening character is inherited in a simple manner and is dependent upon one pair of genes for its expression. During the past season an F_2 population of 293 individuals was grown and the ratio was 3.37 normal green-shouldered individuals to one of the uniform ripening. The uniform character appears to be a recessive, and these results agree with the work of other investigators.

Many single plant lines have been established, some of which are in the F_6 generation. The main difficulty has been to obtain lines which have sufficient foliage to provide an ample coverage for the fruits and thus prevent sunburning. Many of the original lines were determinate in habit of growth; that is, the main stem grew for a short distance and then was terminated by a blossom cluster. Any subsequent growth was made by lateral branches.

Most of the more recent selections made have been indeterminate in habit and thus the coverage of foliage is much better. Also, this type of plant can be pruned and trained to a much greater degree of satisfaction. It is planned to multiply the seed of the three best lines so that they can be sent out for trial among a number of vegetable growers.

Sweet Corn Breeding. (W. H. Lachman.) The object of the corn breeding program has been to develop a hybrid which would provide earliness, productivity, disease resistance, and quality. During the past five years a system of inbreeding has been practiced in an effort to obtain superior inbred lines with characteristics which are sought in the hybrid. Approximately 100 such inbred lines have been obtained and the work now consists of testing the inbreds in various combinations of crosses to ascertain which of the combinations are most desirable.

During the past summer 40 such combinations were planted and carefully studied during the growing period. Five of these performed especially well and have been recommended for further trial. If they grow and produce as well in another season, the seed stock will be multiplied and sent out for trial among a number of vegetable growers. More combinations of the inbreds have been made and will be tested further.

Hybrid Sweet Corn Trials. (W. H. Lachman.) Hybrid corn has taken the country by storm. Many varieties have been introduced lately and the list grows longer each year. It has been recognized, however, that each hybrid has a narrow range of adaptability because they are susceptible to very small changes in environment. Hence, regional tests must be made before any hybrid can be recommended for production within very narrow limits or localities.

Therefore, tests are conducted each year, particularly of the yellow varieties, to observe earliness, yield, quality, disease resistance, and general adaptability for this locality. Of the hybrids that have been tested for the past three years four are especially noteworthy.

Spancross (C4×C13) is an extra early, very productive hybrid, and matures in about 70 days. It has good quality, is very uniform and has a medium-sized ear measuring about 6¼ inches in length. This variety is two or three days earlier than Golden Early Market.

Marcross (C6×C13) has a large ear, about eight inches long and is an early-maturing variety. It is only four or five days later than Spancross but not quite so good in quality.

Marcross (P39×C13) also known as Carmelcross is a mid-season variety which matures in 80 to 82 days. This variety produces a large ear and has excellent quality and appearance.

Golden Cross Bantam is a late market corn which matures in 85 to 89 days. It produces a good crop of cylindrical, well-filled ears that are of exceptionally fine quality. This variety is highly recommended.

The Effects of Mulching Tomatoes and Peppers. (W. H. Lachman and G. B. Snyder.) Each season soil moisture becomes one of the most limiting factors in the production of vegetable crop plants. Any treatment or practice which will aid in conserving soil moisture for plant use during critical periods becomes especially significant to the vegetable grower.

Various mulches have been applied to the soil and compared with clean cultivation in the culture of tomatoes and peppers. Straw, banana fibre, and horse manure were the materials used. Based on the results of the tests for two years, it is doubtful whether mulches have a significant influence on yield, cracking, or quality of the fruit.

If mulching was continued for several years it is conceivable that the increase in organic matter might exert a more marked influence on growth and production. The applications of banana fiber changed the soil pH from 5.7 to 7.0, but this change was not reflected in the growth of the plants.

Samples of soil were taken from each of the plots and chemical analyses made by Philip H. Smith of the Control Service. The results show that the various treatments had a rather insignificant influence upon the mineral content of the soil. The soil under the banana fiber mulch is considerably higher in potassium, but other differences are either lacking or not significant.

Cucumber Seed Treatment. (O. C. Boyd and W. H. Lachman.) Samples of pickling cucumber seed were obtained and treated to control seed-borne diseases as well as diseases caused by soil-inhabitating organisms. Dusting the seeds with red copper oxide, whether they had been previously soaked in mercuric chloride solution or not, just doubled the stand of seedlings. The principal benefit of this treatment was the prevention of seed decay and pre-emergence damping-off, rather than the prevention of post-emergence damping-off. There was no evidence of injury to germination by any of the treatments.

Sources of Organic Matter for Greenhouse Tomatoes. (W. H. Lachman and G. B. Snyder.) The scarcity of animal manures as a soil amendment has led to a search for substitute materials. The main object was to find a cheap material which would provide a good source of organic matter and support the growth of greenhouse tomatoes. Straw and peat moss were the two materials best suited for the problem. Straw has proved to be the better of the two materials and is more economical. Both materials, however, must be supplemented with sufficient commercial fertilizer to compensate for the nutrients supplied in manure.

Tri-State Cooperative Vegetable Variety Project. (G. B. Snyder and W. H. Lachman.) This project is conducted in cooperation with the Rhode Island and Connecticut Experiment Stations. The object is to ascertain the influence of the various climatic and edaphic factors upon several strains of beans, sweet corn, peppers, cabbage, celery, tomatoes, and carrots. The data for four years are now being summarized.

Bean Culture. (W. H. Lachman and G. B. Snyder.) One of the limiting factors in the culture of lima beans has been the sparse stand of plants obtained because of poor germination. A rather comprehensive test was made of the value of "Spergon," a commercial preparation used as a dust on the seed. The seed treatment increased the germination about 25 percent and the treated plants were more robust and healthy than the untreated lots.

A number of varieties of edible soy beans have been tested for two years. The varieties "Giant Green" and "Willomi" performed especially well and have a very pleasing flavor. One of the reasons why the public has hesitated to accept soy beans as a vegetable is because they are so difficult to shell. It has been found that the beans shell very easily if they are first boiled for about three minutes. The beans can then be cooked and served much the same as lima beans.

Asparagus Investigations. (Robert E. Young, Waltham.) The yields of 450 plants in five different lines derived from previous selections were in a somewhat different order from those of last year. The yields did not increase as would be expected for asparagus plants that have been cut only two full cutting seasons. The strain that produced the greatest yield last year was second in 1941.

Although the production of the best strain was about double that of the poorest strain and of plants from commercial seed growing alongside, the results of these individual cutting records show that there is a wide variation in the performance of the plants of even the best strain. That the yield can be doubled in one generation establishes great possibilities in asparagus breeding.

Increasing the yield gave a slight increase in the percentage of extra large stalks, and a slight increase in the average weight. In checking the performance of the 25 highest yielding plants it was found that there was a great variation in the type of spears produced. Some plants produced very few large spears but many small ones, while others giving as much in total yield produced mostly large-sized stalks, although when the strains were taken as a whole this difference did not show to any great extent. In the best strain 24 percent of the plants produced a bunch of asparagus (1.25 pounds), while in the commercial strain only 2.5 percent produced as much.

At the time of the fall stalk count, quite a number of plants had rust in varying degrees of severity, including the commercial line of Mary Washington, supposedly rust resistant. The percentage of rust present in the selected strains in the order of their yield was 14.2, 17.0, 13.0, 5.0, 3.3, compared to 39.7 percent for the commercial strain. This would indicate that progress can be made in obtaining not only better yield but also better resistance to the rust disease.

The various characteristics of yield, size, bud shape, height of branching, spreading of tips, and color are so variable that new selections will be made next year to secure more uniformity.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.)

Trellis Tomato. The program of developing better internal and external fruit quality in our two strains of trellis tomatoes has been continued. For reasons not wholly understood, the yield of the 1941 tomato crop was only about 50 percent of last year's although the plants set and the care given were better. Poor tomato crops were reported all along the eastern seaboard. The dry weather, no doubt,

had its effect, but our plants were irrigated and did not suffer for water. The earliness was not affected but there was a general lack of vigor and insufficient foliage.

A number of hybrids were made in the greenhouse last year in order to introduce certain characters of quality, also to test other varieties as to their value in combining with our strain to produce a satisfactory hybrid. One of the varieties used was Victor, a new determinate type, early, with uniform ripening of the fruit. At that time it was thought that the uniform ripening character was a desirable one for our strains. The hybrids of this cross did not have the usual vigor of the other tomato hybrids. The stems were weak and small. Insufficient replicates were grown to make possible an accurate determination of yield but the yield of early fruit was not so heavy as would be expected. During the season observations were made of the way the fruit of the Victor, and other varieties having uniform ripening character, colored and there is now a question whether this character is desirable in our trellis types. A cross between Trellis No. 22 and a late, vigorous Comet was much later than would be expected. This cross was made to obtain more foliage for a tomato of the No. 22 type.

From the behavior of these and other hybrids, it would seem that our trellis type tomatoes exert very little effect on the hybrids in which they are used.

It has recently been reported that the hybrid vigor of summer squash exhibited in the F_1 generation was carried over into the F_2 population. This F_2 lot of plants, while showing segregation as to size and shape, still had earliness and yield. If this fact should be true for tomatoes, it would be easy to produce the F_2 population from a few hand-pollinated hybrid fruits. To determine whether tomatoes will behave in this way several plots were grown of the parents F_1 and F_2 of Waltham Forcing × Early Rutgers. The poor crop made it difficult to evaluate the results but it would seem that the F_2 of this hybrid was about as good in production as the F_1. Further study will be made of this factor and a rating of the desirability of other varieties as parents in such a program.

During winter meetings with the growers the question has been asked as to the value of using early started tomato plants. Certain growers felt that an older plant will produce earlier. To test this contention seed of the Waltham Forcing tomato was sown on February 15. The plants were carried along slowly and transplanted several times, but at setting time they were really overgrown. They were not potted but dug out of the bed with a ball of soil. These plants had ¾-inch fruits at setting time. The regular crop was started April 1 and transplanted in a bed in the greenhouse 2×2 inches, then to the coldframe 4×4 inches. These plants also were set with a ball of soil. It is true that the early started plants had ripe fruits very early, but they were small; during the first three pickings they produced an average of 8.5 fruits that weighed .92 pound per plant, compared to 11.3 fruits weighing 1.6 pound per plant obtained fron the regular crop. The total yield from the early started plants was 1.95 pounds compared to 2.69 pounds from the plants started at the regular time, and from these results it would seem that if plants are to be started early they must be grown in pots or baskets. These plants were very slow to start growth after setting.

Greenhouse Tomatoes. During the year trials of various hybrid tomatoes have been made to see which will combine with the Waltham Forcing and Bay State to produce a good tomato with hybrid vigor. An F_2 generation of a cross between Waltham Forcing and Michigan State Forcing was also grown, and the results indicate that the F_2 plants are vigorous. The yield was very high although the fruit was not very uniform.

A discovery that may make the production of hybrid seed much easier is that the tall non-productive plants that have frequently been found in the Waltham Forcing strain in the greenhouse are only partially sterile. Pollen from good

plants will cause the sterile plants to set seed. If these plants can be used, there will be no need of emasculating the flower to obtain hybrid seed.

Summer Pascal Celery. This year 20 different single-plant selections of Summer Pascal celery were tested to determine whether a longer petioled strain could be obtained; and no irrigation was supplied after the paper for bleaching was applied, in order to determine whether there were differences in the susceptibility to heartburn. Some of the single-plant selections showed almost 100 percent heartburn, while the best had only 25 percent. This severe heartburn provided an opportunity to make selections that did not heartburn for the supply of stock seed.

The results of trials in past years have shown that seed from selected celery plants grown in the fall cannot be raised in time for the next year's crop. Experimental work with light and heat has not hastened the seed stalk development to any extent. A crop of seed was raised outside to provide ample supply of stock seed for our growers. The demand for Summer Pascal celery is greatly increasing.

Greenhouse Lettuce. The third generation of a cross between Bel-May and an English variety, Cheshunt Giant, was grown at the Waltham Field Station and in two growers' houses. Selections were made and seed produced of the most promising. The hybrids have darker green color and better overlapping of leaves on the bottom, and are slower bolting to seed. It will require another generation or so to completely remove the off-type plants from the strain.

Rutabaga or Cape Turnip. A good crop of turnips was produced on the Field Station grounds. As a result three distinct types have been selected, and sufficient seed will be grown to enable the growers to try them on their own farms. Type No. 1 has white flesh with white or light green shoulder, and the root is almost uniformly colored from top to bottom. Type No. 2 has white flesh with a slight purple shoulder. Type No. 3 has yellow flesh but is otherwise of the same character as Type No. 2. Most yellow-fleshed turnips have a dark purple shoulder.

The type of soil at the Field Station is such that a good turnip crop is not assured each year and if further work is needed it should be done in the turnip sections such as Bristol County.

Wyman Crosby Beet. There seems to be a definite correlation between speed of growth and color in beets. The larger roots of the Wyman Crosby strain of beet always seem to be of poor color, while the small roots are usually a dark red color. Twenty-five different selections of single and mass roots were grown and several proved to be very uniform and somewhat of a compromise in that they were of dark color and medium speed of growth. It will require time to build up sufficient seed to try these out on a large scale.

Greenhouse Cucumbers. About 30 different strains and varieties were grown for self-pollination in the field. Some of the strains are approaching sufficient uniformity to permit the hybridization program to be undertaken. Some experimental hybrids tried during the year have been outstanding in yield. The past year's crops have shown that there is a large difference in the vigor of the various lots under trial. Only about 40 percent of the self-pollinated blossoms set fruit, and further study will be made of the methods of pollination and also the effect of homozygous conditions of fruit setting.

Green Sprouting Broccoli. Both the spring and fall crop have afforded an opportunity to make selections of the crosses made during the winter in the greenhouse. Crosses were made between several quite widely different types. The

F_1 generation has shown that there is a large difference in uniformity between hybrids made between homozygous parents and crosses in which one or both parents were from commercial strains. It will require considerably more testing before the real value of any of the lines can be determined.

Hutchinson Carrot. The F_4 generation of a cross of Hutchinson × a Turkish red carrot was grown during the fall. While many of the other vegetable crops this season were poor, the carrot crop was the best in years. The hybrid material was so promising that several lines will be increased for further testing on a larger scale. These new lines have a very uniformly colored root and have a pleasing external color much darker than the Hutchinson.

The stock seed crop of Hutchinson carrot was very small. The plants blossomed profusely but only a small percentage of the flowers set seed. It is probable that the dry weather was not conducive to proper fertilization. To meet the demand for this seed from the seedsmen, a large crop of roots was grown and placed in storage for next year's crop.

Lettuce, New York Type. Three crops of lettuce grown during the season have shown that the strain of lettuce which, because of past performance, was thought to be the most satisfactory will not stand during hot weather without bolting to seed. The early crop, in which plants are set, was small but satisfactory. Comparisons were made, and the better selections showed up well. The first crop in which the seed was planted directly in the field, and which matured in early July, indicated that the best selections definitely had resistance to tip burn.

In this planting was some of a newer selection about ready for release by the U. S. Department of Agriculture which showed excellent heading characteristic, but was small and so crisp as to make it questionable whether it would stand handling in the market. The characters this lettuce has will be combined with our bigger strain resistant to tip burn, which should combine all the desirable characters needed to make a good lettuce for Massachusetts. The fall crop of lettuce confirmed the results obtained in the summer crop.

Samples of the best selections now on hand will be given to a few growers for trial next year.

DEPARTMENT OF POMOLOGY

R. A. Van Meter in Charge

The past season was in strong contrast to that of 1940 in many respects. It opened early and fruit trees bloomed earlier than in any other of the past twenty years. Rainfall was very deficient in the spring of 1941, normal or above in June and July, and low for the last of the summer. Rainfall was heavy in the spring of 1940 and light in the fall, while fruit bloom was late. The rainfall for the summer of 1941 was less than three fourths of the normal amount in Amherst and still less in some parts of the State. Yet tree growth was good at Amherst and apples grew to normal size. The explanation may be largely in the good rainfall for June and July. Trees came through the spring drouth on reserve water from the winter. Soil water drained away early, admitting air to the soil and favoring early root activity and later leaf development. Summer rainfall was enough to maintain growth. Dry weather in the spring is favorable to fruit trees provided it does not continue too long.

Peach fruit buds survived the winter and a good crop was produced. Raspberry canes winterkilled badly, with a consequent reduction of the crop.

The Influence of Various Clonal Rootstocks on Apple Varieties. (J. K. Shaw and L. Southwick.) The new stock bed set last year made a good growth and should yield several thousand rooted layers in 1942. Several new stocks from the United States Department of Agriculture were added. No layers were taken from this bed this year but the old bed yielded a crop of layers that were lined out for budding. Layers from the more vigorous stocks can always be budded the first season but the dwarfing stocks require good growing conditions if they are to be suitable for budding in their first year.

The cooperative clonal stock orchards are as reported last year. Some are doing well and should contribute to our knowledge of the interrelations of these stocks with our American varieties; others are failures. One orchard that did very poorly for the first three years has improved greatly in the last two years. It is on a shallow soil with a high water table in the spring. During the past two years it has been cultivated with a crop of string beans. The reason for marked improvement may be that aeration of the soil has improved conditions for root activity. An additional cooperative orchard of over 1000 trees on these clonal stocks will be planted next spring.

All the trees in our own five-year-old orchard continue to grow about alike. They have been in cultivation and have borne few apples, yet they are now large enough to bear a bushel or more each. The orchard will soon be seeded to grass which should bring the trees into bearing promptly and show whether the trees on the various stocks react differently. Two trees of Red Spy on the very dwarfing Malling IX, one with several apples, broke off, emphasizing the fact that trees on this stock should have support.

The McIntosh orchard planted in 1928 grew better than last year. Comments on the mulched areas are made in the report on the Mulching Project. As measured by trunk diameter, McIntosh trees on Malling XII, XV, and XVI and on their own roots are now larger than the trees on seedling roots; trees on Malling X and XIII are somewhat smaller; and trees on Malling I, V, and VI considerably smaller. Trees on Malling IV are almost as large in trunk diameter and spread of top as those on seedling roots but are not as tall, indicating that this is a promising stock for fruit growers who wish to avoid tall trees.

The trees on various stocks in the 1939 orchard continue to grow about the same; little indication of dwarfing effect of the stocks has yet appeared. A few scattered trees bore apples. In midsummer leaf scorch and partial defoliation appeared. The symptoms suggested magnesium deficiency and an analysis of leaf samples supported this. The trees were given a liberal application of potash (with nitrogen) in the spring of 1941 and it has been shown that potash applications bring out symptoms of magnesium shortage. The situation will be studied further and steps taken to remedy it.

The diameter of the bulge or swell at the point of union and that above and below the union were measured in June. The diameter above the union always averaged smallest. The swell was larger with the stocks known to be dwarfing, and was influenced also by the scion variety. It is doubtful whether the size of the swell is of much significance in the performance of the trees. This work will be more fully reported elsewhere.

Lethal Incompatibilities between Clonal Stocks and Varieties of Apples. (J. K. Shaw and L. Southwick.) The above project is concerned with stock-scion combinations that may be useful in orcharding. There have appeared some combinations that fail sooner or later. We have been unable to make some of the flowering crabs grow on some of these clonal stocks. Cases are known in which comestible varieties fail. Deeming this situation worthy of study, a new project has been started in an effort to learn the reason for such failures.

Tree Characters of Fruit Varieties. (J. K. Shaw, A. P. French, O. C. Roberts, and L. Southwick.) This project has been carried on for many years. As new varieties are constantly appearing there seems to be no end in sight of a need for such work. Varieties of apple, pear, plum, cherry, and peach desired for observation are maintained in the nursery. The usual inspection of nurseries for trueness to name was made, but certification under the auspices of the Massachusetts Fruit Growers' Association was discontinued this year. If trees are kept true to name in the nursery row, the chances of a grower getting trees not true to name is small; and it was felt that the relatively expensive certification was not worth while.

The Genetic Composition of Peaches. (J. S. Bailey and A. P. French.) Special attention was given to the inheritance of blossom characters. Results indicate that blossom type (showy or nonshowy blossoms) is controlled by one pair of genes (Shsh), with the nonshowy type dominant, and that blossom size is controlled by one or more other pairs of genes. This work will be reported in the *Proceedings of the American Society for Horticultural Science.*

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) This project was continued as in the past but a new project referred to elsewhere was started on one of the complete-fertilizer plots. Another plot is used for the mulching experiment and is referred to under that project. The remaining five plots continue to indicate that on this soil a balanced fertilizer is now necessary. It suggests that the fruit grower who is using nitrogen alone as a fertilizer should watch for indications of a shortage of other elements. As long as nitrogen alone results in satisfactory performance of the trees it should be continued, but any symptoms of shortage should be promptly diagnosed and the deficiency supplied.

Comparison of Cultivation and Heavy Mulching for Apples. (J. K. Shaw.) The two small plots where heavy mulching was begun in 1922 continue as reported last year. The mulch material decays rather slowly and bids fair to last several years without additional applications. The trees continue to grow and bear well although grass grows vigorously up through the mulch.

Additional mulch was applied to plot 3 in the cultivation-sod orchard. The material was weighed this year. It amounted to 4225 pounds applied to 10 trees or about 5½ tons per acre. Probably this amount applied annually is more than is economical. Rootlets are much more abundant just beneath the mulch than in surface areas under cultivation or sod. Doubtless there are three conditions that would favor such root development: (a) better and more uniform moisture supply, (b) more readily available nutrients, and (c) better aeration. The growth on these trees this summer was remarkably good and the crop was the largest of any of the seven plots in the orchard. When the mulching was begun four years ago nitrogen must have been very low and the cover crop was negligible. The mulch was applied to almost bare soil. Yet there never have been any signs of nitrogen depression following these liberal applications of waste hay. The trees immediately improved in vigor and production and continued to do so in successive years. No fertilizer, other than the mulch, has been applied for twenty years.

The two plots in the McIntosh clonal stock orchard received additional mulch this second year. The material weighed 13,300 pounds or about 6½ tons per acre. This again is an excessive amount and will be reduced in the future to see if equally satisfactory results can be obtained. The rest of the orchard was seeded in August 1940, to a mixture of red, alsike, and Ladino clovers. A good stand was obtained and now consists mostly of Ladino clover. The clover areas (about two acres) were fertilized with 150 pounds nitrate of soda and 200 pounds nitrate of

potash with an additional 2 pounds nitrate of soda per tree applied under each tree, no clover growing there. The mulched trees received no other fertilizer. The two lots of trees look about the same. Root development beneath the mulch is similar to other mulched plots.

The Effect of Orchard Mulches on the Plant Nutrients in the Soil. (J. K. Shaw in cooperation with the Chemistry Department.) This is a new project. Previous work has shown that nitrates and replaceable potash abound in orchard soils beneath a hay mulch. We wish to know whether this is also true of other mineral nutrients and whether it is due solely to nutrients in the mulch or to soil conditions brought about by mulching. Two 30-year-old McIntosh trees growing in cultivation were mulched with hay, two with glass wool, which may be expected to produce similar soil conditions, and two are continued in cultivation. Two trenches were dug under each tree and soil samples at several depths were taken. These are now being analyzed to determine total and available nutrients. Similar samples will be taken one or more times each year and analyzed.

Studies of Varieties of Fruits. (J. K. Shaw and Staff.)

Apples. Milton trees bore a good crop this year. As trees get older the irregular shape of the fruit is less pronounced than is that of young trees. Milton is larger, of more attractive color, and later than Early McIntosh; the tree is of far better growing habit and begins to bear earlier.

Sweet Cherries. There are no commercial sweet cherry orchards in Massachusetts; yet it would seem that growers in this State might compete with those who ship in considerable quantities of fruit. Leaf spot and brown rot can be controlled easily. The two most serious difficulties are winter injury to the trees and depredations by birds. Proper choice of site and soil and suitable soil management will go far towards preventing winter injury and it is doubtful whether birds would be very troublesome in orchards of an acre or more. Birds harvested most of the blueberries in two small unprotected plots, but when two acres were planted the mischief of birds became insignificant. It has been suggested that captive hawks or even stuffed hawks might scare away birds. In a limited trial in one of our small blueberry plots a live hawk seemed to keep birds away. It should be remembered that only certain species may legally be kept in captivity.

We have grown in the nursery about twenty-five varieties of sweet cherries and most of them are also in our orchard though not all are in bearing. A few notes on some varieties are here given:

Bing is a dark, red cherry often in our markets. It is meaty, of attractive appearance and good quality, with a small pit. It is not very productive.

Black Republican is another dark cherry of good quality but not very large. It is commonly used only as a pollinator.

Dikeman is small, rather sour and of not very good quality. It is not to be recommended.

Giant is a large, dark cherry, inferior in quality to others of its class.

Napoleon is the yellowish Royal Ann of the Pacific Coast and our markets. It is perhaps the best light colored sweet cherry but not as hardy to cold as other varieties.

Schmidt is one of the best dark cherries, of very good quality and fairly hardy. It is recommended to plant with Windsor as a pollinating variety. Nelson is very similar to if not identical with Schmidt. Paul Rose is a yellow bud sport of Schmidt with a red line down the suture. Neither is superior to Schmidt.

Windsor is the best sweet cherry for Massachusetts. It is dark red, hardy, productive, and of very good quality.

Gold or Starks Gold was very productive and hardy at first. Later the trees were killed apparently by winter cold. It is poor in quality.

Sweet September is a late yellow cherry which is now being advertised by some nurserymen. It appears to be too tender to cold for Massachusetts.

Peaches. Duke of York. An old English peach recently brought to the attention of American peach growers. It is an early white-fleshed peach but is unattractive, poor in flavor, has soft-melting flesh, and is semi-cling. Its value in Massachusetts is very doubtful.

Goldeneast. This is a fine, large, freestone, attractive, yellow-fleshed, mid-season peach of very good flavor. It looks very promising.

Redrose is an attractive white-fleshed, late, freestone peach. Flavor was not very good.

New Jersey 102. A medium-season, yellow-fleshed, freestone peach of good quality but not outstanding.

New Jersey 105. A yellow, late, freestone peach; quality only fair.

New Jersey 108. A late, yellow-fleshed, freestone peach; quality poor. Probably ripens too late for Massachusetts.

New Jersey 109. A late, white-fleshed, freestone peach of fair flavor. Not attractive. It may be a little late for Massachusetts in some years.

New Jersey 111. A late, yellow-fleshed, freestone peach, attractive but of only fair flavor. Heavy crop for small tree.

Sungold. A medium-late, yellow-fleshed, freestone peach of very fine flaver and attractive. It has a thick, tough skin and should ship well. The tree is dwarfish and spreading like J. H. Hale.

Grapes. In recent years the New York Experiment Station has bred and the New York Fruit Testing Association introduced many new varieties of grapes. The following varieties are all of this origin:

Erie is a good, early blue grape. The bunch is poor and it is self-sterile. There are better grapes of its season. It seems to be no longer offered by the Fruit Testing Association.

Hanover, Sheridan, Urbana and Wayne all matured fairly well this year but usually our season is too short for them. It is doubtful if any of them should be planted here except under conditions most favorable for maturity.

Several varieties not yet named were fruited. Number 12236 (red) and 12238 (reddish blue) have received the most favorable comment and are regarded as promising. Concord Seedless (blue) and numbers 9975 (blue), 11361 (reddish blue), 11412 and 11679 (both green) appear less promising.

Raspberries. Marcy is still free from mosaic disease, of good quality but rather soft for shipment. It is more desirable than Taylor but it is doubtful if it can replace Latham as a commercial variety.

Marion is a purple raspberry with the undesirable color of that type. It is thought to be superior to Sodus and worth trying if one wants a purple raspberry.

Tahoma appears to be undesirable. The berries are small, soft and sour.

Taylor suffers severely from Mosaic, and its quality is inferior to Marcy.

Among five numbered seedlings from Geneva, No. 13618 seemed most promising. Numbers 5371, 5548, 13108 and 14685 were, for various reasons, considered to be of doubtful value.

Blueberries. Concord. This variety produced very attractive, firm, fine-flavored berries in 1941. There was no tendency to crack after rainy periods. Most berries were large but size was somewhat variable. The scar is large and watery with a tendency for the skin to tear.

Dixi is yet too young to give a good idea of the variety. Bush appears vigorous but yields have been light. Fruit late, large, of good flavor, picks easily, but has a large watery scar.

Jersey. Large, attractive berries make this look like a good variety. The bush is vigorous and yields well. Flavor is excellent if the berries are allowed to ripen well on the bush but very sour if picked a day or two too soon.

June. This variety has improved in growth since the soil was drained, but growth is still weak in comparison with other varieties. Since it is earlier than Cabot, it might have a place for home garden use or roadside stand trade.

Pemberton. This variety continues to look promising because of large size and attractiveness of berries and good yield. Fruit has excellent flavor but the scar is large. There was very little cracking after rainy periods.

Scammell. This variety is probably not adapted to this climate. Leaves are small and growth is not vigorous. Berries are large during first of season but late berries are small. Flavor is good. Berries are firm but they cracked after rainy periods.

Stanley. The performance of this variety was disappointing this year. Growth was poor and yield very light.

Wareham. Berry size was unusually large this year—90 per cup at the start of the season—and held up well. It has a distinctive wild blueberry flavor that some people like. The bush is open and the fruit clusters are small and open, making picking easy. The scar is small. It yields well, but the dark-colored fruit lacks attractiveness. This year it became soft and cracked very badly after rains, and kept poorly in storage.

Fruit Bud Formation in the Strawberry. (R. A. Van Meter.) Differential mulching experiments brought this study to an end with the harvesting of the 1941 crop. Results are now being summarized.

Nature of Winter Hardiness in the Raspberry. (R. A. Van Meter and A. P. French.) One of the serious difficulties of the raspberry grower in Massachusetts is winter injury to the canes and buds. The occurrence is erratic and unpredictable. Little seems to be known about the causal conditions. A study will be made of the rest period, vegetative condition, and chemical composition of the plants in their relations to winter injury. Several seasons' work are likely to be necessary before definite results can be reported.

Storage of Apples in Modified Atmospheres. (L. Southwick and O. C. Roberts in cooperation with Department of Engineering.) Experiments with 40-quart milk cans as gas-tight containers were continued. Attempts were made to maintain definite atmospheres in the cans by daily flushing with nitrogen, by taking out excess carbon dioxide, and by controlling ventilation. The cans were filled on December 2, 1940, with about 35 pounds of rather mature, wrapped McIntosh apples and sealed immediately. These apples at 40° F. generated carbon dioxide at the approximate rate of 2.5 milligrams per hour per kilogram of fruit. Where a sodium hydroxide scrubber was used to wash out the accumulations of carbon dioxide, the oxygen in the cans was reduced to below 3 percent in 8 to 10 days. Complete oxygen depletion was greatly hastened when cans were flushed with nitrogen every day or two.

It was difficult to maintain the desired constant atmospheres in these cans by the methods employed. Since the apples occupied as much as 50 percent of the total space in the cans, respiratory activity itself caused rather abrupt changes in the composition of the atmosphere. Furthermore, a very brief washing period reduced the carbon dioxide content to practically zero. The carbon dioxide increased to an average of 10 percent in the cans between scrubbings. Oxygen percentages varied much less widely around the desired 2 percent level. It was somewhat difficult to keep the oxygen level sufficiently high to prevent anaerobic

respiration unless ventilation was provided. One tight can was left undisturbed with a subsequent CO_2 accumulation of over 60 percent of the total atmosphere.

Through controlled ventilation, one can was operated approximately on the English system of 10 percent oxygen and 11 percent carbon dioxide. With an open 3/8-inch vent near the base of the can, respiration at 40° reduced the oxygen below the 10 percent level. By controlling the amount of leakage through a similar hole at the top of the can, the desired atmosphere was maintained fairly well. Only a very small top opening was needed to allow sufficient air leakage to counterbalance oxygen utilization.

On March 1, one can was opened. The atmosphere in this can had been maintained at less than 1 percent of oxygen with the CO_2 averaging around 12 percent. The apples were in poor condition with scald, skin ruptures, and some internal breakdown. The more highly colored apples were in the best condition both in appearance and eating quality. The flesh was rather soft. A slight alcoholic taste was evidence of anaerobic respiration.

On May 1, another can was opened. The oxygen content of this can had averaged about 2 percent with the CO_2 ranging between 3 and 10 percent. Most of the apples were in good condition with excellent color and no evidence of scald or internal breakdown. There was some soft rot and mold where apples had been injured. Quality was fairly good. A duplicate can was opened two weeks later and here, also, the apples were in good condition though the quality was mediocre. A rather high acidity was a contributing factor.

The can which was operated on the English system was examined on May 13. The oxygen level had varied between 8 and 15 percent. With this system, the sum of the oxygen and CO_2 always equals about 21 percent. There was no scald, core breakdown, or rot, but quality was rather poor.

Where flushing with nitrogen was utilized and a very limited amount of ventilation provided, apples were still in good eating condition on May 13. The oxygen in the can had varied between approximately 2 and 6 percent and the CO_2 between 2 and 12 percent. Just why this treatment gave the best results is not clear unless it was due to the frequent change of atmosphere in the can. The apples (at 40° F.) were better than checks kept at 32°–33° F.

These tests indicate that more uniform control of the atmosphere in a modified-atmosphere storage room is a requisite to the successful operation of such a room. Undoubtedly, the wide fluctuation in the composition of the atmospheres in the cans was a determining factor in lowering eating quality.

The storage room which was "gas-proofed" in 1940 was not sufficiently tight to allow respiration to reduce the oxygen to the desired 2 percent level. A contributing cause of this failure was the fact that brine coils and the shape of the room allowed for only partial filling. This room was opened for inspection at 10 a. m. on February 24 and closed again at 5 p. m., resulting in a total loss of the artificial atmosphere. The oxygen was again lowered to around 10 percent which proved to be the minimum obtainable. The room was opened on March 24 and the fruit placed in another room at 32° F. The Wealthy and Gravenstein apples were past good eating condition; Cortland were fair to good; Delicious were very firm and in excellent condition. Golden Delicious were also in excellent condition and, where individually wrapped, these fruits showed no shriveling. McIntosh comprised the bulk of the apples. These were fairly ripe but not too much so for immediate use. Quality was good and somewhat better than that of similar apples stored as checks at 32° F. (Checks stored at 40° F. in normal air showed internal breakdown.) There were considerable differences between different lots of fruit. In general, the late picked McIntosh had the best quality. High color was associated with high quality. Some rot was in evidence on individual fruits. Many apples did not hold up well at room temperatures, largely because

of overmaturity. Those kept at around 34° F. retained fair eating quality for at least a month. A few fruits subsequently split open.

During the summer certain leaks in this room were corrected, the coils were removed, and a small automatic blower system was installed. This arrangement allowed for the storage of 100 additional boxes. With the 300 bushels, mostly McIntosh, this room is now considered sufficiently full and gas-tight for effective operation as a modified-atmosphere storage room. It was filled and temporarily sealed up in October but later the apples were removed in order that some alterations might be made. It was again filled and sealed on November 27. Previous leakage tests indicated less than 5 percent leakage per 24 hours. At the time of this writing (December 20), this storage is performing satisfactorily. The oxygen level is now down to 2 percent.

It is entirely possible that modified-atmosphere storage, especially for McIntosh, may shortly displace in some degree conventional cold storage methods. It seems to offer advantages that are very desirable and perhaps necessary for the continued prosperity of the industry.

Study of "Bud Sports" of the McIntosh Apple. (J. K. Shaw and L. Southwick.) Trees of 21 so-called "bud sports" were planted in the spring of 1941. Three of these have been propagated for several years, while the others are selections from orchard trees. Half of these are on dwarfing and half on vigorous stocks. The purpose of this planting is to maintain the selections and to see what color type of apples they bear. Most of them are supposed or known to be non-striped strains.

Trees of six forms are ready for orchard planting next spring for the purpose of measuring accurately not only the color type of the fruit but also the vigor, productiveness, and other characteristics of both tree and fruit.

Nutrition of the High bush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) Mixing lime with the soil reduced the growth of blueberry plants. Mixing 5 percent peat with the soil reduced slightly the bad effects of the lime. This work was reported in the *Proceedings of the American Society of Horticultural Science* 38, 1941.

An experiment was started in the spring of 1941 to compare the value of cow, horse, and hen manure as fertilizer for blueberries. Manures have been thought to be harmful to blueberries, especially when applied on soils with a pH above 5. To date the plants look fully as good as those fertilized with mineral fertilizer.

Blueberry Culture. (J. S. Bailey.) During the summer a diversion ditch was constructed around the experiment station blueberry planting so that trouble from erosion should be reduced to a minimum.

The plantings yielded a little over 3000 quarts as compared with 2000 quarts in 1940.

Experiments to control the cranberry fruit worm on blueberries by dusting were continued. Because so few worms were present, even in the checks, the results were not conclusive.

The budding work of 1940 was a complete failure. The bud shields stuck to the stocks but the buds died. This work was repeated in 1941. The buds were set low and protected for the winter by piles of sawdust.

Since the war has cut off the supply of imported peat which has been quite generally used for propagating blueberries, a substitute must be found. A comparative test of several domestic peats was started in the spring of 1940. Nothing which is superior to the imported peat has been found. A leaf mold from Massachusetts and a sphagnum peat from Maine compare favorably with the imported peat.

A light supplementary application of ammonium sulfate about June 7 was given all the blueberries except those in the manure test. The improved appearance of the plants and the increased yield over previous years indicate that this was a good practice.

Bulletin 358, Blueberry Culture in Massachusetts, was revised.

Premature Dropping of McIntosh Apples. (L. Southwick.) Work on this project largely concerned investigations with "hormone sprays." Some chemicals such as naphthalene acetic acid and certain of its salts, naphthalene acetamide and some others, have been shown to delay natural drop of apples at harvest when applied in dilute spray solutions. These chemicals and several commercial proprietary compounds employing these active ingredients were used in field tests in 1940 and 1941. Bulletin 381, published in February, 1941, summarized the results of experimental work conducted in 1940 and in it the authors attempted to evaluate the method of "hormone spraying" especially in relation to McIntosh. Further tests in 1941 revealed no very different results. There was some evidence that under certain conditions, drop-control sprays on McIntosh were not so effective as in 1940. Many check trees dropped comparatively little this year. In most cases, however, the preharvest drop from sprayed trees was less than that from check trees in the same block. Some typical percentage drop comparisons, sprayed and unsprayed, follow: 3.7 and 14.5 percent; 12.9 and 20.2 percent; 2.3 and 7.5 percent; 10.2 and 13.4 percent; 11.6 and 21.4 percent; 7.3 and 18.5 percent; 13.9 and 13.4 percent. It is apparent from these figures that degree of control was not consistent.

There is some indication that the temperature at the time of application may be important. Possibly fruit growers should wait for temperatures above 60° F. before applying a drop-control spray. A more definite statement on this point must await further experiments.

A limited test with Milton indicated little benefit from spraying. The sprayed trees dropped 31 percent of the total crop compared with 34.6 percent from the check trees.

Results again demonstrated the desirability of using standard strength sprays with McIntosh. Weaker sprays were usually less effective. Doubling the standard strength increased the effectiveness of applications. How much improvement in drop control would be required to offset the increased cost of stronger sprays is problematical and depends on several factors. It can be stated with some assurance, however, that the so-called standard strength of "hormone sprays" should not be reduced with McIntosh in this State.

The use of special stickers or summer oil seems to merit some consideration. Theoretically, these materials should tend to improve coverage. Actually, the benefits from their inclusion in hormone sprays have been variable. Usually, drop control has been somewhat better although in some cases improvement has been negligible. It is at least certain that spreaders and stickers are not effective substitutes for good coverage.

Dusts were tried this year for the first time. These were made up by two commercial concerns and were compared with spray applications. In about half the tests, dust was only slightly inferior to spray in lessening pre-harvest drop. In the others, dusting was not effective. It is true also that spraying was practically ineffective in some cases. The heavier applications of dusts (4 pounds per tree) seemed more effective than lighter dosages. Until further evidence is at hand, the use of hormone dusts by growers is recommended for trial only.

Miscellaneous Work

Soil Acidity in the Orchard. Lime was applied to a Sudbury orchard in which aluminum toxicity was suspected, as mentioned in the report of last year. It appears that both grass and trees were improved by the treatment. With the increasing use of wettable sulfur the danger of injuriously high acidity becomes greater. Not only is there danger of aluminum toxicity, but nitrification in the soil decreases as the soil acidity increases.

Lime and Phosphorus in Planting Trees. We have as yet no evidence that phosphorus is directly beneficial to apple trees on our soils; we know that it is readily fixed in the soil and it follows that orchard applications may not pass into the relatively deep-rooted apple trees. An orchard of 36 McIntosh trees of a single strain on three clonal stocks was planted in the spring of 1941. One third of the trees were treated with 10 pounds dolomitic limestone, one third with 5 pounds triple superphosphate, and one third were untreated. The materials were placed in the bottom of the planting holes and well mixed with the soil. As measured by trunk diameter increase, the trees treated with lime grew most, those treated with phosphorus least, while the untreated trees were intermediate.

Weed Killing. The attempt to get rid of wild cherries, particularly choke cherries, around the peach orchards was continued. A new weed killer, ammonium sulfamate, was tried. It looks very promising. Used at the rate of ¾ pound per gallon water, one application was enough to kill small choke cherries and kill or badly damage black cherries. Chlorate weed killers used at the same strength were not so effective on choke cherries and were ineffective on black cherries.

Ethylene Dichloride Emulsion for Control of Peach Tree Borers. Because of reports of damage from the use of this material in other sections, it is being thoroughly tested in the station orchards. It has been used in 1939, 1940, and 1941 in one orchard and in 1940 and 1941 in several others. Applications have been made at 15-day intervals during the fall. The emulsion has been used (1) according to directions, (2) at slightly higher concentrations, and (3) in slightly larger quantities, than recommended. Only one case of injury has occurred; some very vigorous late-growing suckers from the base of some trees were injured when applications of the emulsion at the concentration for three-year old trees was applied. This was an overdose for the year-old suckers. Unseasonably hot weather following the application may have had an effect. Injury has never occurred when applications were made according to standard directions.

Sawdust Mulch. In the summer of 1938, a sawdust mulching program was begun in a small block of bearing apple trees An average of about 4 inches of sawdust was placed under alternate trees to determine the effect of sawdust on subjugation of sod, on soil nutrients and acidity, and finally on tree growth and production The sawdust had little effect in subduing the grass, which proceeded to grow apace throughout the summer and fall. Unlike hay or straw, which tends to mat down, sawdust does not tend to smother grass. No additional applications were made during the next three years. Neither deleterious nor particularly favorable effects on soil or tree have been observed to date.

In November and early December of this year, a considerably greater amount of sawdust was applied to the same trees. This time, however, the sod on half of the area under the branch spread was taken up and the soil shaken out. The other half was left in sod. Sawdust to an average depth of 6 inches was applied over the whole area. It is intended to determine the comparative feasibility of using a sawdust mulch on cultivated soil and on sod in a bearing orchard.

DEPARTMENT OF POULTRY HUSBANDRY

R. T. Parkhurst in Charge

Broodiness in Poultry. (F. A. Hays.) A number of specific facts have been established in this study of the inheritance of the broody instinct in Rhode Island Reds. Some of the most significant findings are the following. The length of the non-productive period associated with broody behavior remains rather constant at about fifteen days. Degree of broodiness as measured by the number of broody periods is governed by inheritance. The time of appearance of the broody instinct in the life of a female is highly variable. In flocks bred to eliminate the broody instinct, the onset of broody behavior in individual females has been about 57 percent in the first laying year, 34 percent not until the second laying year, and about 8 percent not until the third laying year. These three classes of females when used as breeders gave about the same percentages of broody daughters. The selection of female breeders that did not exhibit the broody trait during their first two laying years was effective in reducing the incidence of broodiness in the flock. There is no evidence of sex-linked inheritance.

At present efforts are directed toward the establishment of an entirely non-broody line by applying all of the information now in hand.

Statistical Study of Heredity in Rhode Island Reds. (F. A. Hays and Ruby Sanborn.) This project is devoted entirely to the preparation and analysis of experimental data used for publication. During the year the following papers have been prepared: The Importance of Length of Incubation Period in Rhode Island Reds, Bulletin 384; Breeding for High Viability, a study covering seven years, has not yet been published; A Preliminary Study of Molting Behavior, covering three years, has not yet been published; and A Study of Variation in Egg Weight, covering five years, is now in preparation.

A Genetic Study of Rhode Island Red Color. (F. A. Hays.) This study has to do with the genetic complex concerned in the inheritance of Rhode Island Red plumage and possible relationships between characters affecting fecundity and plumage color. Two lines of birds are being carried, one breeding true for late sexual maturity and the other selectively bred for early sexual maturity. There is some evidence that one or both of the dominant genes for early sexual maturity affects plumage color. The relation between the red of the Rhode Island Red plumage and the buff of the Orpington is also being studied.

Rate of Feathering in Rhode Island Reds. (F. A. Hays.) This experiment is concerned primarily with the genetic aspects of rapid and slow chick feathering. To study this problem three lines have been developed with respect to rate of chick feathering; namely, a rapid-feathering line produced exclusively by the use of breeding males that showed complete back feathering at eight weeks of age; a slow-feathering line bred entirely from sires showing the absence of back feathering at eight weeks of age; and a check line bred primarily for high fecundity, with some of the sires rapid feathering and some slow feathering.

In the spring of 1941 the seventh generation was produced in the three lines, and gave the following percentages of rapid-feathering sons at eight weeks: line 1, 100; line 2, 10; and the check line, 84. The chicks were also classified for the sex-linked gene for rapid feathering at twelve days of age. The males in the three lines gave the following percentages with the sex-linked rapid-feathering gene: line 1, 49; line 2, 0; and the check line, 6. An attempt was also made to separate the rapid- and slow-feathered females by grading the feather growth in the back region at four weeks of age.

All data available indicate that in Rhode Island Reds the sex-linked gene for

rapid feathering may or may not be present in rapid-feathered stock. There is, however, a definite sex difference in the rate of feathering in the dorsal region.

The Effectiveness of Selective Breeding in Reducing Mortality in Rhode Island Reds. (F. A. Hays.) This is a cooperative project with the Regional Poultry Research Laboratory, East Lansing, Michigan. In the spring of 1934 a project was begun to test in a small way the effectiveness of selective breeding in reducing mortality in Rhode Island Reds.

The foundation stock consisted of pedigreed birds that had been bred for characters associated with high fecundity since 1916. During the first five years females alone were kept to the age of 18 months. Beginning with the sixth generation, hatched in 1939, both males and females were retained to the age of 18 months. An attempt has been made to establish two lines, one for low mortality and the other for high mortality. Breeding males and females 24 months of age were used as breeders and the sole basis of their selection was the mortality rate of their sisters during their first laying year. A check line consisted of birds bred for high fecundity. Inbreeding in both lines was avoided by the constant use of males drawn from the check group but selected on the mortality basis. Limited facilities available permitted the production of about 100 birds in each of the mortality lines, and since 1939 about equal numbers of males and females have been carried to 18 months of age. Complete mortality records have been kept and post-mortem examinations have been performed by the Department of Veterinary Science.

The limited data now available indicate in general that selective breeding was effective in small groups in reducing the mortality rate from the miscellaneous diseases and disorders appearing under our conditions.

Genetic Laws Governing the Inheritance of High Fecundity in Domestic Fowl. (F. A. Hays and Ruby Sanborn.) Many phases of this problem have been studied and reported upon. At the present time special attention is being given to the genetics of intensity and winter pause. These two characters have a rather complex inheritance and their interactions with other characters are very significant. Possible interactions between genes affecting intensity and genes affecting egg size are being given close study. The mortality problem as affected by selective breeding is also being given constant attention.

Recent findings indicate that chicks emerging early from the shell are likely to be superior from the standpoint of fecundity; that heavy body weight in both males and females at six months of age is a significant criterion of future low mortality; and that selective breeding for characters affecting egg production has not reduced the viability of the stock. Reducing the variability in egg production is a slow process because of the complex nature of inherited factors and environmental interactions.

A Study of Fertility Cycles in Males. (F. A. Hays.) Histological studies of testes from males in a wide age range, taken throughout a two-year period, indicate that both age and season affect the rate of spermatogenesis. There is definitely a cyclical behavior in males with respect to their fertility. Preliminary breeding tests have not indicated that fertility is governed by inherited factors. This problem of possible inherited factors is being studied further along with environmental factors that may be in operation.

Physiological Relationships Between Molting Behavior and Fecundity Characters. (F. A. Hays.) Bi-weekly individual molt records are being continued on a fourth series of males and females from parents with known molt records. The first breeding stage of this project began in the spring of 1941. Two lines

were started, the first from females laying but few eggs during molt and the second from females laying for a relatively long period during the molt. Preliminary studies over three years indicate that the ability to lay eggs and molt simultaneously is a highly desirable trait. The change in body weight of males and females during the annual molt is not very significant. Males already used required an average of about 94 days to shed their wing primaries while females averaged about 119 days. Some females lay very few eggs during this period while others lay up to 40 or 50 eggs. Good females should shed at least three primary wing feathers before laying stops. Completion of wing molt in December appears to be desirable from the standpoint of first-year egg production.

Miscellaneous Genetic Studies. (F. A. Hays.) Linkage studies include genes for shank feathering, comb form, and mottled ear lobes in Rhode Island Reds. An effort is also being made to isolate the sex-linked gene for early sexual maturity. A new method for separating sexes in Rhode Island Red chicks is being studied and offers some possibilities. For auto-sexing, a gold-barred bird is being developed on a limited scale.

The Use of Crab Meal in Poultry Rations. (Raymond T. Parkhurst and Marie S. Gutowska with C. R. Fellers of the Department of Horticultural Manufactures cooperating.) In broiler production studies, Red-Rock cross chicks were used and comparisons involved the 1940–41 New England College Conference starter as the basal ration, the basal ration with 5.5. percent crab meal replacing 2.5 percent fish meal, the basal ration with 5.5 percent crab meal replacing 5 percent milk and 2.5 percent fish meal, and the basal ration with 3 percent fish meal replacing 5 percent of dried skimmilk. The mineral contents of the rations were adjusted. There were no significant differences in growth, mortality, feed efficiency, feathering, or pigmentation.

When crab meal replaced fish meal on an equal-protein basis (4 pounds for 2.5 pounds) in the Massachusetts complete all-mash laying ration, there were no significant differences in egg production, weight of eggs, feed efficiency, yolk color, albumen quality, fertility, and hatchability. The egg production averaged higher in the fish meal group, based on the birds that lived, but fewer birds died in the crab meal group; with the result that total production, total income, and the feed cost per dozen eggs were practically the same for the birds on the two rations. The results to date show that crab meal is a satisfactory ingredient in poultry rations and can replace fish meal on an equal-protein basis. Further comparisons of these feeds are in progress.

The Manganese Requirements of Laying Hens. (M. S. Gutowska and R. T. Parkhurst.) The effect of the addition of manganese to complete all-mash laying rations was investigated from a practical standpoint. Forty-eight Rhode Island Red pullets were kept on a basal all-mash ration for 12 lunar months (2 periods each lasting 6 lunar months). The two high-manganese groups received in their diets 76 and 61 parts per million of manganese; the two low-manganese groups, 17 and 24 p. p. m., respectively. The data showed no appreciable differences in egg production, feed efficiency, fertility, hatchability, and livability between the compared groups; but the shell-breaking strength of eggs laid by the pullets on high-manganese rations was significantly greater than that of eggs laid by birds on the low-manganese rations, although the shell texture was not unsatisfactory in the latter groups. It was concluded, because all-mash laying rations containing as little as 17 and 24 p. p. m. of manganese did not produce manganese deficiency symptoms in laying hens in a period of 12 lunar months, that even these levels in laying rations can be considered satisfactory from a practical viewpoint.

The Effect of an Excess of Calcium in the Diet. (M. S. Gutowska and R. T. Parkhurst.) The results of this experiment showed that an excess of calcium in the ration of laying hens lowered the production value of the diet, and that 3.95 percent of calcium in the diet of laying hens having a normal dietary level of phosphorus and ample vitamin D intake was excessive. However, there was no significant difference in the egg shell breaking strength, the average egg weight, and the fertility and hatchability of eggs between the groups of birds receiving the varying levels of calcium.

The importance of a control of the mineral balance of laying rations by means of chemical analysis at regular intervals is suggested.

The Value of Pulverized Calcite Flour as a Source of Calcium for Laying Hens. (M. S. Gutowska and R. T. Parkhurst.) The object of this experiment was to compare qualitatively two rations with different sources of calcium: pulverized plain calcite and oyster shell meal, at the same quantitative level. The manganese content of the rations was estimated to be close to the assumed optimum for laying pullets.

The data obtained from two flocks of 24 Rhode Island Red pullets during 12 months showed no significant differences in production, body and egg weight, feed efficiency, egg shell breaking strength, hatchability, and fertility. The egg quality was equal in the two flocks.

It was concluded that pulverized plain calcite is as good a source of calcium as oyster shell meal for laying pullets; but its biological value as a mineral supplement for laying hens is not higher than that of oyster shell meal.

The Phosphatase Activity as a Factor of Calcium Deposition and Egg-Shell Formation. (M. S. Gutowska and R. T. Parkhurst, with the cooperation of E. M. Parrott and R. M. Verberg of the Chemistry Department.) Phosphatase activity as a factor of shell formation is studied by the determination of plasma and oviduct phosphatase activity. Four groups of hens, good and poor producers, with good and poor egg shell, are being compared in this regard. The phosphatase activity is determined according to a modification of King-Armstrong method.

Electric Brooding. (W. C. Sanctuary in cooperation with Professor C. I. Gunness of the Engineering Department.) The use of soil cable under 4 inches of sawdust litter materially reduced moisture content of litter, when used continuously, but at an excessive cost. The use of insulation plus restricted ventilation also reduced the moisture content of the litter materially, but not so much as the continuous use of the soil cable. The use of damp (40 percent moisture) sawdust from the start of brooding produced no deleterious results except for a large number of crooked toes thought to be due to cold floors. Because of high moisture content, the litter froze into a solid block on cold nights.

Combining Meat and Egg Production. (W. C. Sanctuary and J. H. Vondell.) The standardization of body weight in Barred Plymouth Rocks at 6 pounds by December 1 has been well established. The 1938 generation had a mean weight just below 6 pounds. The generations of 1939 and 1940 had a mean weight just a trifle above 6 pounds. There has been some improvement in meat quality as measured by fleshing upon the breasts at 8 weeks of age and later as adults. One adult male of the 1941 generation has approached the extreme "broad-breasted" type now produced in one variety of turkey. Egg production has improved also, three 300-eggers having been produced in the last two years largely because of improvement in intensity (rate) of production.

Sexing by Down and Shank Color. (W. C. Sanctuary.) The sexing by down and shank color of 948 College pedigreed Barred Rock chicks was done with a 95.36 percent accuracy compared to a 95.15 percent accuracy by the vent process method with the same chicks. The chicks were first judged by the down and shank characteristics.

Restricted Feeding on Range. (J. H. Vondell.) At 10 weeks of age, one half of the College Barred Rock chicks was placed on a restricted plan of feeding, while the remainder continued on the free-choice feeding of mash, oats, and corn.

The restricted plan consisted of feeding mash and oats until 10 a. m., when the hoppers were closed and no feed given until the 4. p. m. allotment of whole corn. The pullets were housed September 12 and both lots were placed on full feeding. The restricted plan resulted in a saving of 1.52 pounds of feed per chicken during the 15-week period. At 6 months of age the restricted and full-feeding lots weighed exactly the same, 5.85 pounds. There was no difference in maturity as determined by age at first egg. The laying-house mortality to April 1 was practically the same for the two lots. Also, egg production was quite close: 57.86 percent for the full-feeding and 62.88 percent for the restricted lot.

These studies are being continued.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, O. S. Flint, and M. K. Clarke.)

1. *Pullorum-Disease Eradication.* During the 1940-41 season the laboratory tested 309 chicken flocks representing 527,328 birds and 538,589 tests. The percentage of reactors (0.09) was the lowest in the twenty-one-year testing period. Of the total 478 reactors, the bulk was identified in one flock.

Testing service was rendered to flock owners in 11 counties. Middlesex and Worcester counties led in the number of birds tested. No reactors were found in Barnstable, Essex, Hampshire, Plymouth, and Worcester counties.

Five flocks which were non-reacting the previous year revealed infection during the 1940-41 season. In two instances a plausible explanation for the infection was obtained. In all instances but one the percentage of reactors was very low, less than one-half of 1 percent.

Flocks tested for the first time revealed the highest percentage of infection. Among the flocks (41) tested for two consecutive years, no reactors were found. Among the 210 flocks tested for three or more consecutive years, representing 437,145 birds and 446,694 tests, 0.08 percent reactors was revealed.

Approximately 88 percent of the total birds tested was confined to 100 percent tested, non-reacting flocks (256). Forty-three flocks were partially tested and non-reacting, representing 28,874 birds. Ten flocks were classified as positive, representing 34,853 birds.

Of the total birds tested, 490,759 were females and 47,830 were males. The percentages of reactors were 0.08 and 0.17, respectively.

A total of 4,417 samples collected from fowl other than chickens was tested for pullorum disease. The species tested included turkeys (4,259 tests), pheasants (115), guinea fowl (22), geese (13), ducks (5), and quail (3). Reactors were detected in three of the 32 turkey flocks, but in only one instance was *S. pullorum* isolated. No reactors were detected among the other fowl tested.

The testing results indicate that Massachusetts is making progress in eliminating pullorum disease from its chicken and turkey breeding flocks.

2. *Diagnostic Service.* During the year, 2,264 specimens were examined in 533 consignments. Personal delivery of specimens was made in 335 cases. The specimens may be classified as follows: 1,878 chickens, 256 turkeys, 38 canine feces, 24 pheasants, 11 each of foxes and goat feces, 7 pigeons, 6 trout, 4 bovine semen, 3 each of crows, peafowl, and ruffed grouse, 2 each of bovine organs, bovine skin scrapings, calves, canine, equine nasal swabs, mink, rabbits, and sheep, 1 each of bovine rumen contents, canary, equine, and pork.

The incidence of the more common and important disease conditions observed in chickens during the past five years is as follows:

	1936-37	1937-38	1938-39	1939-40	1940-41	Total
Avian tuberculosis	1	1	3	1	1	7
Coccidiosis	35	64	97	82	63	341
Enterohepatitis	2	7	6	7	7	29
Epidemic tremor	8	35	22	19	12	96
Fowl cholera	11	3	16	12	13	55
Fowl coryza	5	2	1		3	11
Fowl paralysis	37	45	77	47	51	257
Fowl pox	8	30	21	7	9	75
Fowl typhoid	4	2	11	4	1	22
Infectious bronchitis	40	31	48	57	31	207
Infectious laryngotracheitis	12	9	19	14	13	67
Internal parasites	23	21	41	26	34	145
Kidney disorders	17	15	37	21	19	109
Leukemia	7	3	6	3	5	24
Nutritional encephalomalacia	1	7	13	8	6	35
Paratyphoid	1	2	3	1		7
Perosis	4	2	4	3	3	16
Pullorum disease	39	46	49	32	28	194
Reproductive disorders	22	14	20	21	17	94
Rickets	8	6	19	19	10	62
Tumors	53	46	79	53	66	297
Ulcerated gizzards	1	15	14	15	10	55
Unknown disease	9	11	24	26	33	103
Unknown pullet disease	6	6	11	9	14	46

The 256 turkeys were received in 44 consignments. Paratyphoid, coccidiosis, enterohepatitis, and ulcerative enteritis were the conditions most frequently encountered. Pullorum disease was observed only once for the second consecutive year and these poults came from a source outside of the State. Pullorum disease was, however, established in a Massachusetts flock through necropsy of a reacting turkey. Swine erysipelas and fowl cholera were each identified once. This is the first time that fowl cholera has been recorded in a Massachusetts flock. *Capillaria contorta* was identified twice in one flock. This parasite produced symptoms in quite a number of birds in both instances.

Capillaria plica was observed in one fox. We are indebted to the Zoological Division, Bureau of Animal Industry, United States Department of Agriculture for identification of the parasites in the fox and in the turkeys.

Listerellosis was identified in a canary. All females (eight) in the aviary died within a two-week period. The males in a separate cage were not affected.

3. *Flock Mortality Studies.* These studies have been continued to obtain additional data on causes of adult mortality and to furnish information for genetics experiments. Necropsy examinations were made on 208 morbid and dead birds from the flock which was hatched in the spring of 1940 at the Experimental

Poultry Farm. There were 147 females and 61 males. A wide variety of diagnoses was made on these birds, but no unusual outbreaks of disease were noted. The mortality in this year's flock was widely distributed over the year, whereas the mortality in flocks hatched in previous years had a tendency to be concentrated in the late spring or just after the birds were more than one year of age. Cannibalism was materially reduced in this group of birds, whereas fowl paralysis and staphylococcosis were markedly increased.

4. *Salmonella Types Isolated.* The identification of paratyphoid organisms isolated from diseased specimens continued during the past year, and 21 were added to those previously reported. Eighteen were *S. typhi-murium*, one was *S. anatum*, and two (from different organs of the same specimen) appear to be a new type. These 21 strains came from six flocks. One strain was isolated from a pigeon and all others from turkeys (7 mature and 13 poults).

During the past year, 4104 turkey blood samples were tested for paratyphoid infection by the macroscopic tube agglutination test. An autogenous antigen of *S. typhi-murium* was used as a test fluid. While infected birds can be detected by such a procedure, the method can not be relied upon to eliminate the infection to the degree accomplished in pullorum-disease testing. Owners of flocks that are apparently free of this infection should investigate thoroughly the history of the source from which stock may be introduced.

We are greatly indebted to Dr. Philip Edwards, Department of Animal Pathology, University of Kentucky, Lexington, Kentucky, who identified these strains as to type.

5. *Avian Encephalomyelitis.* The infective agent was passed through chicks (intracerebral inoculation) 21 times during the past year and is now in its 125th passage since its first isolation. Its characteristics do not appear to have undergone any permanent change during the twelve months. An attempt was made to determine the presence of avian encephalomyelitis virus in the brain of adult birds which had exhibited typical symptoms of the infection as chicks. Six hens of this type were destroyed and brain suspension prepared from each for inoculation intracerebrally into baby chicks. In no instance did the brain suspension produce symptoms of avian encephalomyelitis. A suspension prepared from the ovary of one of the six birds also gave negative results when inoculated into baby chicks. The virus appears to lose its potency very slowly if stored at 10° C. ±. This conclusion is based on inoculation of three brain suspensions prepared 10/8/38, 4/12/39, and 8/24/39 and stored until 1/21/41. The oldest (stored 837 days) produced typical symptoms in 50 percent of the chicks inoculated; the next oldest (stored 650 days), in 67 percent of the chicks; and the most recent (stored 517 days), in 86 percent of the chicks.

Additional data were obtained from inoculation of embryonated eggs and transmission of infection to chicks hatched in the incubator at the same time with the inoculated embryos. A total of 188 ten-day embryos was inoculated in six different settings of eggs. Of the 91 chicks hatched from these embryos, 23 showed typical symptoms of avian encephalomyelitis. Seven of these chicks showed symptoms before they were taken from the hatching tray, and one chick showed no symptoms until it was 29 days of age. All others showed symptoms at ages between these extremes. None of the 107 chicks exposed in the incubator while hatching developed symptoms of avian encephalomyelitis infection. The effect of fumigation on brain suspensions of avian encephalomyelitis virus was investigated in three trials. Chicks inoculated with a virus suspension previously fumigated by the standard formaldehyde gas method did not develop clinical symptoms.

Consignments of chick brains were received from Georgia, New Mexico,

Ohio, and Wisconsin. Avian encephalomyelitis was definitely identified in three of the four consignments.

6. *Infectious Bronchitis Studies.* During the past year investigations were undertaken in the control of infectious bronchitis, which is a widespread, highly infectious, communicable respiratory disease of chickens causing serious losses among young chicks and laying birds.

Field investigations were started with the objective of inoculating flocks during the growing age in the hope of producing an immunity which would be of sufficient duration so that the birds would pass through at least one laying season without contracting the infection. Fourteen flocks, representing approximately 40,000 birds, were inoculated during the months of June, July, and August. The inocula were prepared from laboratory birds inoculated with a known infectious bronchitis virus. Preliminary observations reveal that birds ranging in age from four weeks to four months can be inoculated without serious objectionable post-inoculation results. However, the inoculation of birds six to ten weeks of age produced the most satisfactory results. Chicks under four weeks of age and laying birds should not be exposed to the infection.

To date no definite evidence of the disease has appeared among the birds in the inoculated flocks. Later in the season a critical test will be applied to the various flocks to determine their resistance to infectious bronchitis virus.

Laboratory investigations are in progress to develop a practical and economical method for the production and administration of the virus for flock inoculation. The development of a practical and successful inoculation program to control infectious bronchitis will mean a great economic saving to the Massachusetts poultry industry.

7. *Farm Department Brucellosis Control and Eradication.* The laboratory cooperated in this work by testing 639 bovine and 53 swine blood samples, by the standard tube agglutination method.

Studies of Neoplastic and Neoplastic-like Diseases. (Carl Olson, Jr.) The lymphoid tumor experimentally transmissible in chickens has been maintained in serial passage during the past year. It has retained its fundamental characteristics and in its later passages has shown no tendency to change its behavior. Apparently the tumor has assumed a fixed pattern for its action in experimental birds. The results of the first thirty serial passages have been published in an article "A transmissible lymphoid tumor of the chicken" appearing in *Cancer Research* 1: 384-392, 1941.

The collection of 384 spontaneous tumors of chickens has been investigated and much interesting information has been the result of this study. The collection was derived from three sources; namely, cases of tumor submitted to the Diagnostic Laboratory during a two-year period, cases of tumor occurring in a flock from which nearly all birds found ill or dead were examined, and cases of tumor found in birds from other miscellaneous sources. Twenty-three different types of neoplasia were found in the collection. The most common was lymphocytoma, as slightly over half (55.5 percent) of the cases were of this variety. Six other types (leiomyoma, embryonal nephroma, myelocytoma, leukosis, epithelioblastoma, and fibrosarcoma) collectively comprised about one-third (32.8 percent) of the collection. Other varieties of neoplasia found were carcinosarcoma, neurogenic sarcoma, hemangioma, fibroma, cholangioma, hepatoma, histiocytic sarcoma, myxoma, thymoma, rhabdomyoma, osteochondrosarcoma, fibrochondrosarcoma, melanoma, lymphangioma, mesothelioma, and teratoma.

Three forms of lymphocytoma were found: diffuse, nodular, and combined diffuse and nodular. A possible explanation for the existence of three forms was

developed from study of the material, and is based on the inherent resistance of the individual bird to growth of the tumor. Thus in diffuse lymphocytoma the host has but little resistance to growth of the tumor, allowing it to assume a diffuse character. In nodular lymphocytoma the host has considerable resistance to growth of the tumor, causing it to be restricted and nodular in form. The combined diffuse and nodular form develops when there is but moderate resistance of the organ or tissue in which the tumor is growing.

WALTHAM FIELD STATION

Waltham, Massachusetts

Ray M. Koon in Charge

The members of the research staff of the Waltham Field Station are assigned to the unit by the Departments of Botany, Entomology, Floriculture, Horticulture, and Vegetable Gardening. Reports of these departments give results of investigations conducted at this station.

Soil Testing Service. Testing soil for commercial vegetable growers, mushroom growers, florists, nurserymen, greenkeepers, arborists, vendors of loam, and home gardeners has long been regarded as an important service which the Field Station has rendered. More recently this program has been extended to include service to the State Department of Public Works, the Metropolitan District Commission, Works Project Administration, and town and city administrations. There is no doubt that this effort is effective, particularly when the soil test is followed by a personal interview between the client and the technician. The total number of soil samples tested in 1941 was 6676.

Field Day. The twenty-third annual Field Day on August 6, 1941, attracted the usual number of visitors, about 1200. Perfect weather made it one of the most comfortable Field Days ever held. In an endeavor to increase the interest in the vegetable contests a few more varieties were added to the list. Valuable prizes were offered by the Boston Market Gardeners Association for the three best market packages of Bunched Carrots, Summer Pascal Celery, White Celery, Trellis Tomato, Straightneck Squash, Sweet Corn, and Cucumber. An auction of the vegetables entered in the contests proved an interesting innovation.

PUBLICATIONS

Bulletins

378 Annual Report for the Fiscal Year Ending November 30, 1940. 112 pp. February 1941.

The main purpose of this repert is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

379 Trace Metals and Total Nutrients in Human and Cattle Foods. By E. B. Holland and W. S. Ritchie. 31 pp. July 1941.

This information concerning the composition of various plant materials is provided because of the very general interest in the nutritional function of certain trace elements.

380 Pasture Culture in Massachusetts. By William G. Colby. 44 pp. October 1941.

Pastures are of great economic importance in Massachusetts agriculture, and this study represents an attempt to organize such available information as may have a bearing on their best management.

381 Spraying to Control Preharvest Drop of Apples. By Lawrence Southwick and J. K. Shaw. 16 pp February 1941.

The use of "hormone sprays" to reduce preharvest drop is a new development. This bulletin reports results of recently conducted tests in an attempt to evaluate the method, especially in relation to McIntosh.

382 The Propagation of Some Trees and Shrubs by Cuttings. By William L. Doran. 56 pp. March 1941.

The detailed information regarding recent developments in plant propagation dealt with in this bulletin should be of significant economic importance, especially to nurserymen and foresters.

383 The Sanitary Evaluation of Private Water Supplies. By Ralph L. France. 11 pp. March 1941.

A safe water supply for rural homes is of prime importance. This is an explanation of some of the problems involved, with special attention to contamination and its detection.

384 The Importance of Length of Incubation Period in Rhode Island Reds. By F. A. Hays. 12 pp. July 1941.

This represents an attempt to determine whether length of incubation period may serve as a criterion of the future performance of chicks.

385 Natural Land Types of Massachusetts and Their Use. By A. B. Beaumont. 16 pp. May 1941.

This represents an attempt to supply certain technical information regarding soils considered essential as a basis for sound land-use studies and classifications.

386 Rural Youth in Massachusetts. By Gilbert Meldrum and Ruth E. Sherburne. 8 pp. December 1941.

National concern regarding the general welfare of our population deserves some planning, fcr which studies of this sort may furnish a basis.

387 Interrelationship of Land Uses in Rural Massachusetts. By David Rozman. 20 pp. December 1941.

The extent and significance of the various land uses and their relationship to each other is analyzed with a view to providing a balanced system of land utilization.

Control Bulletins

108 Twenty-First Annual Report on Eradication of Pullorum Disease in Massachusetts. By the Poultry Disease Control Laboratory. 11 pp. May 1941.
109 Inspection of Commercial Fertilizers and Agricultural Lime Products. By Fertilizer Control Service Staff. 55 pp. September 1941.
110 Inspection of Commercial Feedstuffs. By Philip H. Smith. 64 pp. October 1941.
111 Seed Inspection. By F. A. McLaughlin. 93 pp. November 1941.

Meteorological Bulletins

625-636, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. By C. I. Gunness. 4 pp. each.

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312 Retention of Vitamins C and A in Glass-Packed Foods. By C. R. Fellers and R. E. Buck. Food Res. 6 (2):135-141. 1941
365 The Effect of Cocoa upon the Digestibility of Milk Proteins. By L. D. Lipman and W. S. Mueller. Dairy Sci. 24 (5):399-408. 1941.
369 Factors Affecting the Toxicity of Red Squill. By J. A. Lubitz, A. S. Levine, and C. R. Fellers. Jour. Amer. Pharm. Assoc. 30 (3):69-72. 1941.
370 Anticataractogenic Action of Certain Nitrogenous Factors. By Helen S. Mitchell, Gladys M. Cook, and Mary D. Henderson. Arch. Ophth. 24:990-998. 1940.
375 The Effect of Dry Heat upon the Anticataractogenic Quality of Certain Proteins. By Mary D. Henderson and Helen S. Mitchell. Jour. Nutr. 21 (2):115-124. 1941.
376 Transmitting Ability in Males of Genes for Egg Size. By F. A. Hays. Poultry Sci. 20 (3):217-220. 1941.
377 The Effect of the Hydrolytic Products of Casein and Deaminized Casein on the Cataractogenic Action of Galactose. By Edwin L. Moore, Mary D. Henderson, Helen S. Mitchell and Walter S. Ritchie. Jour. Nutr. 21 (2):125-133. 1941.
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381 Manganese Absorption in Fowl. By Marie S. Gutowska, E. M. Parrott, and F. A. Slesinski. Poultry Sci. 20 (4):379-384. 1941.
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384 Sex Ratio in Domestic Chickens. By F. A. Hays. Amer. Nat. 75:187-188. 1941.
386 Report on Zinc. By E. B. Holland and W. S. Ritchie. Jour. Assoc. Off. Agr. Chem. 24 (2):348-350. 1941.
387 Laboratory and Business Relationships in Foods and Nutrition. By Carl R. Fellers. Jour. Home Econ. 33 (2):87-93. 1941.

388 Effect of Processing on the Vitamin A (Carotene) Content of Foods. By C. R. Fellers. Proc. of the Food Conf. of the Inst. of Food Technol. held in Chicago, June 16-19, 1940.

389 Toxicity of Red Squill Powder and Extract for Chickens, Rabbits, and Guinea Pigs. By J. A. Lubitz and C. R. Fellers. Jour. Amer. Pharm. Assoc., Sci. Ed. 30 (5). 1941.

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Manganese in Cows' Milk. By J. G. Archibald. Milk Plant Monthly, September 1941.

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Progress Report, including Transcriptions of Certain Papers Presented at the Eighth Annual Five-Day Short Course for Tree Wardens and Other Workers with Trees, March 24-29, 1941:

Poisonous Plants. By A. Vincent Osmun. pp. 28-35.

The Dutch Elm Disease Problem in Massachusetts. By Malcolm A McKenzie. pp. 54-55.

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FM3 Costs and Returns—Snap Beans for Canning in 1940. By Charles R. Creek. 24 pp. January 1941.

FM4 A Farm Management Study of Vegetable Farms in Bristol County, Massachusetts, in 1939. By Charles R. Creek. 27 pp. February 1941.

FM5 Harvesting and Packing Iceberg Lettuce on Farms in Massachusetts. By Charles R. Creek and Richard Elliott. 12 pp. February 1941.

FM6 Harvesting and Packing Tomatoes on Farms in Massachusetts. By Charles R. Creek and Richard Elliott. 12 pp. March 1941.

FM7 Harvesting and Packing Celery on Farms in Massachusetts. By Charles R. Creek and Richard Elliott. 14 pp. May 1941.

FM8 Vegetable Growing in Bristol County, Massachusetts, in 1940. By Charles R. Creek. 20 pp. October 1941.

FM9 Two Years of Vegetable Growing in Bristol County, Massachusetts. 1939 and 1940. By Charles R. Creek. 14 pp. October 1941.

Farm-Management Problems and Suggested Adjustments on Vegetable Farms in Bristol County, Massachusetts. By Normal R. Urquhart and Charles R. Creek. U. S. Dept. Agr., Bur. Agr. Econ. in Cooperation with Mass. Agr. Expt. Sta., Dept. Agr. Econ. and Farm Mgt. 27 pp. June 1941. (Washington, D. C.)

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The following Extension Leaflets were prepared wholly or in part by Experiment Station men during the year ended November 30, 1941.

Home Canning of Vegetables, Fruits and Meats. By C. R. Fellers, W. W. Chenoweth, and W. R. Cole. Mass. State College Ext. Leaflet 142. 24 pp. 1941.

Control Calendar for Vegetable Pests. By E. F. Guba and W. D. Whitcomb. M. S. C. Ext. Leaflet 116 (revised). 24 pp. April 1941.

Pest Control in the Home Garden. By A. I. Bourne and O. C. Boyd. M. S. C. Ext. Leaflet 171 (revised). 12 pp. March 1941.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 389 February 1942

Production and Prices of Milk in the Springfield-Holyoke-Chicopee Milkshed in 1935

By Alfred A. Brown and Mabelle Booth

A comprehensive understanding of the productive organization and the marketing disposal facilities of the fluid milk industry is a necessary basis for sound marketing regulation. To this end, the investigation reported here was undertaken.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

PRODUCTION AND PRICES OF MILK IN THE SPRINGFIELD-HOLYOKE-CHICOPEE MILKSHED IN 1935*

By Alfred A. Brown, Assistant Research Professor, and Mabelle Booth, Technical Assistant, in Agricultural Economics and Farm Management

INTRODUCTION

In the spring of 1934 the people of Massachusetts through their General Court adopted, in the interests of local dairymen, a program which was certain to cause an increase in the consumer price of milk. There was nothing subtle in the presentation of the program to the public. The facts and assumptions were simply stated. They appeared reasonable.

In general the prices which farmers were getting for milk were exceptionally low; the prices which they were paying for goods or services were not proportionately so. Both had been declining since the middle or late twenties. During the early phase, the balance had been fairly well maintained between the price for which milk sold and the cost of goods and services used on the farm. The severe disturbance to finance and industry in 1929 touched off a sharp decline in prices. Milk prices dropped faster and lower than did prices of some items which farmers bought. The lack of balance between farm costs and farm prices became so severe both in degree and duration that many farmers were faced with the loss of their farms.

This course of events was characteristic of the capitalistic system. By it those individuals who by errors of judgment were caught in the backwash were normally forced out of business; by it the most competent producers, whether of milk or of mousetraps, were selected to serve society. Circumstances were such, however, that the public could ill afford to give the system free rein. Some farmers would be included in the purifying process because of factors beyond their control. Of more importance, however, was the threat to the fluid milk supply.

Since the latter part of the 19th century, adequate supplies of wholesome milk have been regarded as necessary to public welfare. Many measures have been taken during the past fifty years to protect the quality of the supply. The operations of the market, however, have been relied upon to safeguard the quantity of the supply. Threats of serious shortage had occasionally occurred under this method, and in the spring of 1934 direct aid by the government in pricing was considered necessary if the supply was to be maintained. Assistance to the dairy industry was facilitated then by the national program to revive all agriculture in the effort to stimulate business. Under the circumstances, though, it is probable that some sort of governmental aid would have been given to the producers of fluid milk even in the absence of a general program.

Sound regulation of marketing depends in part on a comprehensive understanding of the productive organization and the marketing disposal facilities of the industry. To this end, data on the Springfield–Holyoke–Chicopee milkshed have been gathered, tabulated, and analyzed. Studies on Milk Cartage and

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*Data for this study, like those preceding it, were secured with the cooperation of dairy farmers, producers, cooperative associations, distributors, and public agencies having an interest in the milk industry. Many persons in the Department of Agricultural Economics and Farm Management contributed to the study.

Dealers' Product Costs for this milkshed have already been published: Massachusetts Agricultural Experiment Station Bulletins 363 and 365, respectively.

The present study is made up of two parts: the first a description of the milkshed; the second an analysis of producers' farm prices.

TABLE 1.—RATIO OF WHOLESALE MILK PRICES RECEIVED BY MASSACHUSETTS FARMERS TO PRICES PAID BY FARMERS
1910-14 = 100

	Milk Price Index*	Prices Paid Index*	Ratio
1925	125	157	80.2
1926	130	155	83.8
1927	128	153	83.6
1928	134	155	86.4
1929	138	153	90.1
1930	138	145	95.1
1931	113	124	91.1
1932	93	107	86.9
1933	87	109	79.8
1934	97	123	78.8
1935	113	125	90.4
1936	116	124	93.5
1937	111	131	84.7
1938	108	123	87.8
1939	108	121	89.2

*Index Numbers of Massachusetts Farm Products. 1910-1940 M. S. C. Extension Service 1940.

PART I

SPRINGFIELD-HOLYOKE-CHICOPEE MILKSHED

Geography

The farms from which the Springfield-Holyoke-Chicopee market area draws its supply are located in the towns and counties shown in figure 1. Boundaries of municipalities, however, meant little as far as location of the supply was concerned. Roads, topography, relative prices, and alternative enterprises were for the most part the determining factors. The grouping of producers as shown in this figure, partially illustrates the influence of natural conditions. Since no particular attention was given to ascertaining the cause for the individual farmer's selling in the market, the effect of dealer influence can only be surmised. The grouping of producers also illustrates the influences of alternative enterprises. The sparseness of large-scale dairy units in the river bottom land is no surprise to anyone familiar with the high cost land (the burden of which is being met by the intensive cash cropping currently of onions, potatoes, and tobacco). The concentration of production in other areas was the result of natural conditions which are more favorable to livestock production than any other enterprise and of economic advantages arising from priority in and nearness to the market. (Viz. Area 2.)

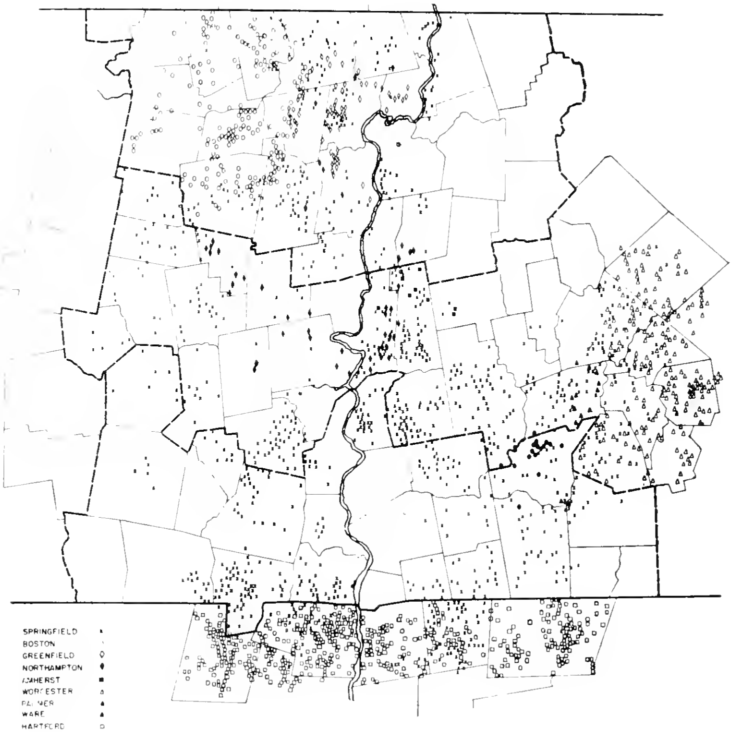

Figure 1. Shippers in the Springfield-Holyoke-Chicopee Milkshed, 1935 Located by Markets*

*Springfield shippers living in New York and Vermont were not located.

In developing the study, the clusters of producers were given an identity designated as "competitive area." A very common observation had been that a particular geographical group of producers was selling milk to a number of dealers. From this it seemed logical to assume that in a relatively small area a degree of competition for the supply might exist. Or if the dealers exhibited no competitive spirit due to the existence of a "buyers'" market, then the producers might have been expected to express a measure of competition for the market. Competition would have existed when either the standardized 3.7 prices or the actual prices to producers were practically uniform. No competition existed.[1] The identity of the areas, however, has been retained as a convenient means of describing the productive characteristics of the shed. (Figure 3.)

Exclusiveness of the Shed

Overlapping supply areas with additional transportation costs is one of the characteristics of the quasi competitive—quasi public-utility system of milk

[1] See section on Prices to Producers.

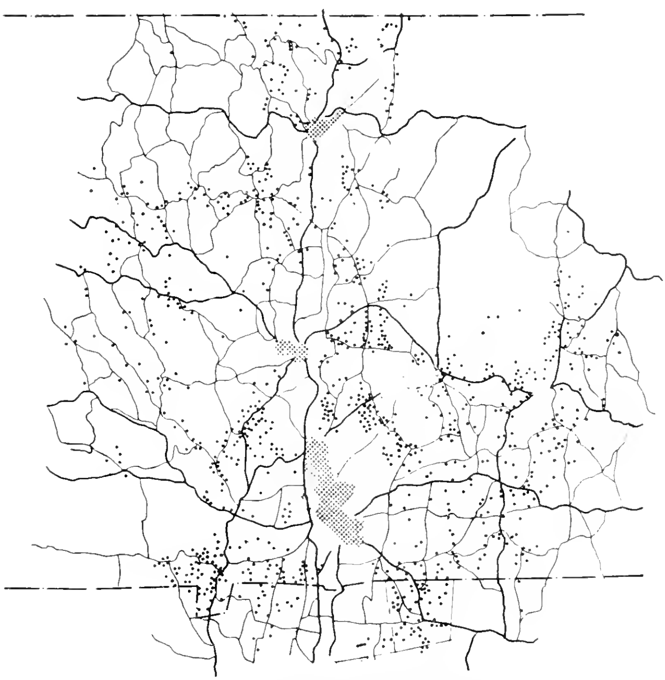

Figure 2. Location of Farms in the Springfield-Holyoke-Chicopee Milkshed in Relation to Roads, 1935

marketing. The region from which Springfield and contiguous municipalities draw their milk supply is on the east a source for Worcester; on the south, for Hartford, Connecticut; on the north, for Boston; and throughout, for the small markets within the larger shed. The overlapping is shown in figure 1.

Disposal of Commercial Production

Based on the shipments of 1853 full-time dairy farmers, the commercial production within the Springfield-Holyoke-Chicopee milkshed was apportioned among the several markets as shown in table 2. Of the annual commercial[2] production within the shed in 1935, local markets[3] took 13.9 percent, Springfield 59.5 percent, and outside markets[4] 26.6 percent. No attempt has been made to determine the extent of seasonal variation in shipments to the market groups other than Springfield. Factors other than seasonality of production were probably generally responsible for producers' market outlets.

The quality standards prevailing in the various markets were in all practical details similar. Inability of producers to meet the standards for a particular municipality could scarcely have been a factor creating supply-market ties.

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[2]That sold off the farm.
[3]Greenfield, Northampton, Amherst, Ware, and Palmer
[4]Boston, Worcester, Hartford.

TABLE 2.—ALLOCATION OF PRODUCTION* OF SPRINGFIELD-HOLYOKE-CHICOPEE MILKSHED AMONG ITS MARKETS

Market	Percent	Volume Annual	Volume Per Day	Volume Per Day Per Dairy	Producers Number	Producers Percent
Springfield	59.5	76,598,361	230,718	195.0	1183	63.8
Local	13.9	17,934,396	49,135	225.4	218	11.8
Outside	26.6	34,221,199	93,757	207.4	452	24.4
Total	100.0	128,753,956	377,309	203 6	1853	100.0

*Full-time Grade B Shippers.

TABLE 3.—AVERAGE VOLUME OF MILK HANDLED DAILY IN APRIL* 1935 BY DISTRIBUTORS OPERATING IN THE CHIEF LOCAL MARKETS

Local Market	Volume of Milk Handled By Producer Distributors	Volume of Milk Handled By Merchant Dealers	Volume of Milk Handled Total	Number of Producers	Number of Distributors
Amherst	5,221	1,664	6,885	14	10
Greenfield	1,700	9,686	11,386	71	13
Northampton	5,146	16,179	21,325	91	21
Palmer	3,421	2,151	5,572	24	12
Ware	4,390	247	4,637	18	15
Total	19,878	29,927	49,805	218	71

*Data available only for month of April.

TABLE 4.—DISTRIBUTION TO OUTSIDE MARKETS

Market	Deliveries Per Day Per Dairy	Pounds Daily	Pounds Annually	Number of Shippers
Worcester	202.1	*18,799	** 6,861,635	93
Boston	169.2	37,219	***13,584,829	220
Hartford	271.5	*37,739	**13,774,735	139
Total	207.4	93,757	34,221,199	452

*Summation of Average Dairy Deliveries.
**365-Day Year Calculated.
***Sum of yearly deliveries of full-time producers.

Number and Distribution of Producers

Program planners for the dairy industry have to decide, among other things, whether their interest is the commercial dairyman or all herd owners; whether their concern is the existing pattern of commercial productive organization and activity or the potential productive organization and capacity of a milkshed. The decisions are not easily made because of the arbitrary element involved in defining the commercial dairyman.

The Agricultural Census for 1935 records 5677 farms reporting "cows and heifers milked" in those Massachusetts towns comprising the bulk of the shed. Regular shippers to the various markets would account for 27.6 percent, part-time shippers for 9.4 percent of this total.

On the basis of reasonable assumptions and estimates[5] the herds of the full-time and part-time shippers had 74.4 percent of the milking cows and likewise accounted for the same proportion of the productive activity of the shed. The balance of the reporting farms would have had two cows or heifers and combined would have produced one-fourth of the total produced in the shed.

TABLE 5.—MILK PRODUCTION IN MASSACHUSETTS
Monthly* 1935

Month	Pounds per Cow Per Day
January	16.0
February	15.9
March	16.8
April	17.9
May	17.4
June	19.1
July	19.0
August	17.8
September	16.8
October	16.7
November	16.8
December	16.2
Total	206.4
Average	17.2

*From Monthly Issues of Crops and Markets U.S.D.A., 1935.

The producers were spread among the market groups on the following basis: Springfield–Holyoke–Chicopee 63.8 percent, outside markets 24.4 percent, and local markets 11.8 percent.

Distribution of Producers Throughout the Milkshed

The heaviest concentration of producers was in the northwestern part of the milkshed, the area in which the Shelburne Falls plant of the H. P. Hood & Sons Company is located. The smallest concentration, almost diametrically opposite, was in Area 3 in the southeastern part of the shed. The ratio of the extremes was five to one.

Variation in the density of production was also very pronounced. The extremes in production, however, were in adjacent areas. In Area 2, the Enfield–Somers

[5]It has been assumed, on the basis of the average production per cow per day as reported by the Crop Reporting Service, and the deliveries per day per dairy as determined in the study, that the herds of "commercial" dairymen averaged 12 milking cows. Applying this estimate to the so-called commercial herds, gives them 25,212 cows and heifers or 74.4 percent of the number tabulated from the Agricultural Census data.

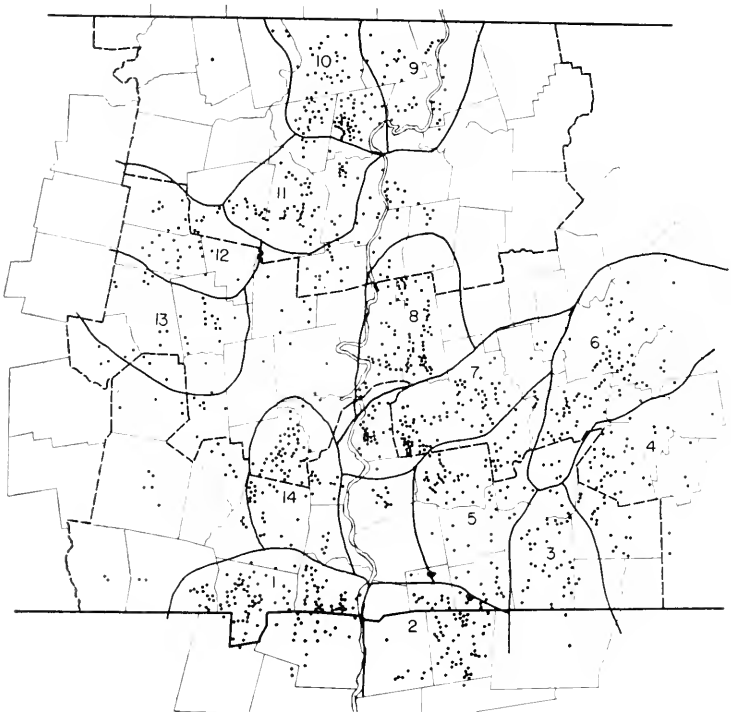

Figure 3. Location of Competitive Areas Springfield Holyoke-Chicopee Milkshed, 1935

TABLE 6.— DENSITY OF PRODUCTION THROUGHOUT THE SPRINGFIELD–HOLYOKE–CHICOPEE MILKSHED, 1935
(Based on Shipments into the Market Area)

Pounds Per Square Mile Per Day	Area	Average Daily Deliveries Per Area	Square Miles
181	2	16,160	89
165	11	13,199	80
161	7	18,136	113
121	6	18,731	155
118.4	8	11,485	97
118	10	8,591	73
112.5	1	13,394	119
112	14	9,949	89
83	5	9,776	118
77	9	5,649	73
52	12	3,885	75
51	4	6,764	132
37	13	3,577	96
34	3	4,210	124

(Connecticut)–Longmeadow (Massachusetts) section, the density of production for the Springfield Market as measured by daily deliveries was 181 pounds per square mile. In Area 3, the Stafford–Stafford Springs (Connecticut)–Munson–Wales (Massachusetts) section, the density was 34 pounds per square mile. These differences can be largely attributed to differences in natural conditions, mainly the soil.

It is interesting to compare the production per square mile in the overlapping parts of the milkshed for the larger markets.

TABLE 7.—DENSITY OF PRODUCTION IN THE OVERLAPPING PARTS OF THE MILKSHEDS SUPPLYING THE LARGER MARKETS, 1935

Section of the Milkshed	Production per Square Mile per Day	Average Daily Deliveries per Section	Area in Square Miles
Northwest*	218	62,708	287
Northeast**	262	44,724	171
South***	337	70,013	208

*The sum of Areas 10, 11, and Shelburne Falls.
**The sum of Areas 4, 6, and Worcester.
***The sum of Areas 1, 2, and Hartford.

The parts of the milkshed are probably better related to each other. This comparison probably reflects more accurately the relative importance of the several sections of the milkshed from the standpoint of production.

Premium Milk

It is not without consideration for accepted practices that a slightly uncommon definition of premium milk is used herein. Many producers and consumers alike believe and have believed that fat (cream) content was the determinant of quality. So far as this study is concerned, resort is made to a less debatable characteristic. "Premium Milk" is that product which commands a price differential on some basis other than butterfat. Some of these bases are bacteria count, vitamin content, medical supervision, advertising, dealer preference, etc.

Relative Importance Throughout the Milkshed

The number of shippers[6] of premium milk was fairly large. Practically 13 percent of all full-time sellers were in this class. The bulk of them, however, sold to dealers outside the Springfield–Holyoke–Chicopee market.

TABLE 8.—SHIPPERS OF PREMIUM MILK

Market	Number of Shippers
Shelburne Falls	220
Springfield–Holyoke–Chicopee	19
Total	239
Percent of All Full-time	12.9

[6]Full Time.

Relative Importance in the Springfield–Holyoke–Chicopee Market

The handling of premium milk is a very minor activity. The volume was equivalent to 4 percent of the full-time Grade B supply. The number of shippers was but 1.61 percent of the Grade B group. Even these ratios overestimate the situation, since the data on premium milk include a few shippers who switched from B to A and vice versa. There is little question but that the shippers of premium milk were a select group. The average daily deliveries of the full-time Grade A shippers were 399.0 pounds compared to 195.0 for the Grade B group. Average fat content (a minor factor) was 4.03 compared with 3.91. Variation in deliveries[7] was confined to narrow limits, from a low of 92.5 percent in February to a high of 107.2 percent in August; while for the balance of the shippers in the shed, the extremes were 90.2 in November and 114.2 in June. Data on bacteria count were available only for the deliveries made by shippers of Grade A and Vitamin Milk.[8] Comparisons of this characteristic are therefore not possible.

So far as value is concerned, the product which the group of premium shippers sold had an average net price of $3.110 per hundredweight, compared with $2.462 for the deliveries of the Grade B group; a difference of 1.39 cents per quart. The extreme prices received by individuals in the premium group were $2.50 and $3.84 per hundredweight; a difference of 2.8 cents per quart. Although there were several kinds of premium milk, the shipper receiving the highest price shipped Grade A without the furbelows of added vitamins.

The existence of a premium market within the general market introduces several interesting questions. There is in the first place the effect of such a market on producer–distributor relationships. Does such a market operate as an additional check on (Grade B) producers by being a false incentive? In a previous study we have shown the wide spreads between dealers' product-costs[9] for the Grade B supply. Producers who supply the low-cost dealers are anxious to move up the ladder to supply the high-cost dealer since high dealer product-costs generally mean high producer prices. It is natural to wonder whether a similar ladder exists with the dealers who handle premium milk? Are the shippers of Grade B eager to be on the premium list? Without exception, in unequalized markets, progress up the pathway of higher prices for milk is by invitation. Under such circumstances, do shippers for the most part become subservient to the dealers? The border between subserviency and common sense is probably a very narrow one.

There is in the second place the relationship between the prices paid to shippers of premium milk and the costs involved in meeting the requirements. Whereas under State Statutes Grade B or Market Milk[10] may have a bacterial count of 400,000 colonies per cc, Grade A–Raw may not have more than 100,000. The lower maximum bacteria count is for the most part the important quality standard of cleanliness around the cattle, barns, milk houses, and pens and must be lower than is necessary in Grade B production. Achievement of these standards[11]

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[7]Seasonality of production in terms of the daily average for the year.
[8]"It is difficult to determine exactly what bacterial standards are pertinent to Grade B producers." (Laws and Regulations Governing the Production of Grade B Milk in New England, R. G. Bressler, Jr., N. E. Research Council on Marketing and Food Supply, June 1938.)
[9]Average price of all milk bought from dairy farmers.
[10]"Rules and Regulations——" Milk Reg. Board, May 8, 1935.
[11]The standards which must be met in the production, distribution and composition of milk before it may be offered to the public are many. They are subject to state regulation, local regulation, and dealer regulation. In the absence of local regulations, those promulgated by the state apply. These state laws and regulations, therefore, may be thought of as minimum requirements to which producers in any town must comply. (Bressler, op. cit. p. 1) The dealer may require shippers selling to him to meet even more stringent regulations than those in force by state or local ordinance.

varies and frequently does entail additional costs. Determination of the cost-price relationships is not within the scope of this study. It is not, however, to be overlooked in a consideration of the organization of supply.

In contrast with these somewhat dismal possibilities due to grade differentials, is a more optimistic one based on the known fact that a market exists which will and can pay a premium for a higher quality product. The market may be small; the quality characteristic, frills so far as a healthful supply is concerned; but buying power is there and the dealer in his desire to increase his net income, to provide outlets for shippers that will enhance the value of the product, or to create good will, endeavors to satisfy the market.

To that end, the dealer will of necessity be the promoter and in turn extend to his shippers the opportunity of filling the requirements. Such problems as might arise would be due to the selection of producers to whom the opportunity is extended. To avoid charges of favoritism or discrimination, presumably the differential paid for premium milk should be no more, in the long run, than sufficient to cover the additional costs of producing and getting it to the market. Whether or not such a nice adjustment has developed can scarcely be determined from analysis of cost data. In substitution for cost analysis, therefore, one might ascertain whether shippers of Grade B are anxious to switch over to the Grade A list, whether Grade A shippers would prefer to change to the Grade B list, or whether both groups are apparently satisfied. Shifts in both directions took place. Since only a few shippers were concerned, no effort was made to determine the causes reponsible for the shift.

Significance of Scale of Production

State regulation of various aspects of milk marketing came into being to protect the Commonwealth's milk supply. In the mandate, however, nothing is said as to whether the state is to protect the commercial milk supply or all who wish to become dairy farmers. The granting of assistance from the state to a special group should be and presumably is based on the assumption of certain responsibilities by the group so favored. Does any difference exist, however, in the desire, the capacity, or the ability of the dairy farmers on varying scales of production to assume responsibility? If so, are the benefits derived by the dairymen individually or in groups commensurate with the degree of responsibility assumed?

What is the nature of the dairy farmers' responsibility? Is it similar to that of distribution? The distributors have maintained, for example, for years that their responsibility was to assure the public wholesome supplies of milk in the quantities desired, at the time and place designated. This obligation was self-assumed; taken on, to be sure, as a matter of self-protection, but none the less taken on.

Under this sort of an arrangement, the dairy farmer had obligations to no one but himself. He met the requirements of the handler who took the daily production from the farm. Failure to meet those standards generally meant that the dairyman lost his market. His was the greatest loss.

Milk control has changed the relationships which prevailed during the past 20 years between the dairy industry and the public. The industry gave signs, reaching a climax in 1932 and 1933, of failing in its obligations to maintain without legal aid an adequate supply of high quality milk. It is sufficient to point out that the returns from the sale of milk had been and were far from sufficient to enable dairymen to maintain their herds. As conceived by the proponents of milk control and agricultural reform and as inferred by the state, not only were the herds and related productive appurtenances to be maintained, but some means should be provided that would keep the present farm operators in business;

that is, management in the person of the dairy farmer was also essential to the public welfare.

The problem was simple to state. The objectives of control were likewise simple to phrase and were about as follows: Returns to the dairy farmer should be such as to (1) enable him to maintain the productive operations on his farm, (2) enable him to have a living from his farm operations that would keep him on the farm or keep the farm a desirable source of livelihood.

The methods by which the objectives were to be fulfilled were not so easily determined. There was general agreement that prices which handlers were to pay dairymen should be artificially controlled. There was much disagreement as to the necessity of controlling prices which handlers should charge consumers. There was an appreciation of the importance of marketing arrangements between dairyman and handler and some provisions were made for minimizing the undesirable practices.

Much of the regulatory effort has been of the preventive variety. This sort was expedient since the industry and presumably the public[12] were very anxious to stamp out certain pernicious practices. The negative approach to conditions within the industry has, however, continued, presumably for two reasons. In the first place, control by regulatory agencies is of the "must-not" type. In the second place, it is much easier to indicate the things or practices which are not wanted and take steps to get rid of them than it is to visualize the things which are desired and devise a plan to assure their attainment. The essential difference between the two approaches is that under the negative, someone is constantly being frustrated and the industry kept in turmoil; whereas under the positive, emphasis is placed on the goal and on the means indispensable to its attainment. Frustration of a sort still exists but alternatives are at least indicated. Tinley[13] says it this way—"Considerations of general welfare indicate the necessity for positive public regulation designed to promote greater efficiency in the distribution of fluid milk." One might also add "and in the productive organization of the fluid milk industry."

When the public, through the legislature, indicated that it wished to adopt a program which upped its fluid milk prices 30 to 50 percent, it did so on the assumption that it was assuring itself of an efficient milk supply—production and distribution. The granting of a privilege, which in this instance is the freedom to charge an arbitrarily high[14] price—a fair price, one determined by judgment rather than by competition—imposes upon the industry the responsibility of providing the consumer with that supply in the most efficient manner possible. Since the dairy farmers themselves are presumably the chief beneficiaries of this public assistance, it behooves them to take the initiative in formulating a program towards this end.

To many persons efficiency in the dairy industry means efficiency in distribution. The somewhat obvious "make-work" characteristics of distribution which have developed in the milk business have overshadowed the gaps elsewhere in the industry; gaps which are becoming increasingly important. A program in which the public welfare is the paramount consideration needs to be concerned with greater efficiency throughout the entire industry. For example—

1. In the operation of the production facilities as well as the distribution facilities.

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[12]It is difficult to understand how the public could be persuaded to adopt a policy that was going to cost it a 30 to 50 percent increase in price for a commodity that is bought every day.

[13]Public Regulation of Milk Marketing in California, p. 46, J. M. Tinley, University of California.

[14]In reference to the competitive market price under current conditions.

2. In the operations of the price-making process.
3. In the administration of the control law.
4. In the designation of broad objectives and in the formulation of policies designed to assure their attainment.

The public welfare concept must be kept paramount so long as the dairy industry is the recipient of special privileges from the public. When the interests of special groups crowd out the general welfare, then the privilege should be withdrawn.

Milk Transportation in the Springfield-Holyoke-Chicopee Milkshed

Importance of Transportation

Under competitive conditions efficiency of operations by the entrepreneur is highly significant. Such operations tend towards relatively low unit costs; business changes are effected on that basis and users of the service can and will be charged relatively low rates.

Competitive conditions do not exist in the hauling of milk. Efficiency of operations is at least secondary to the objective of securing a supply of milk. The charge that producers pay for service under such conditions supersedes service in importance.

Conclusions regarding the efficiency of service in the Springfield-Holyoke-Chicopee milkshed may be drawn from the detailed study of conditions in the Southwick Agawam Area.[15] Other areas adjacent to the market would tend towards similar conditions. Areas more distant from the market would tend to have more efficient transportation operations although the service from the viewpoint of individual producers may not be so satisfactory. It can be assumed almost without qualification that the efficiency of milk transportation in the competitive areas varies inversely with the number of dealers operating in the areas.

The savings which producers might enjoy as the result of a transportation service organized from the standpoint of efficiency rather than from the viewpoint of market arrangements, are probably insufficient to stimulate more than passing interest. A uniform reduction in the cartage rate of fifteen cents per hundredweight on the basis of average daily deliveries of 182 pounds would save producers only twenty-seven cents per day or in a 365-day year, $98.55. Compared to the annual average market value of $1876.83, the potential saving is small and the producer's first interest is to protect his $1800 outlet.

Since 1933 the Federal Government and many of the state governments have been concerned about the stability of their milk markets. The interest of the governmental units is based on the assumption that (1) an adequate milk supply is essential to public health and (2) that unstable markets are a threat to such a milk supply.

One factor contributing to market instability is the unevenness of dealers' buying prices. The control agencies sought to overcome this factor by establishing (1) uniform class prices and (2) proportionate sharing of the fluid and by-product uses. Another factor tending toward unstable markets is the variation in rates charged for transporting milk from the farms to the dealers' plants.

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[15]Massachusetts Experiment Station Bulletin 363.

As yet state control has not seriously attempted any corrective program in this direction.

Rate variation becomes a source of market instability in two ways. In the country, the existence of it tends to create a feeling of skepticism if not distrust among shippers. An attitude of this sort makes the relationship between producer and dealer vulnerable, which in turn is not conducive to permanency.

The extent and incidence of rate-variation influences its force as an element of instability. The range in rates is significant but chiefly when associated with other factors. Should the variation arise between groups fairly well separated, the result would not be so disruptive as if the variation existed between routes within an area or among producers on the same route supplying the same dealer.[16]

Some of the skepticism pertaining to the cartage-rate situation is doubtless due to the location of the rate-making authority. It is difficult if not impossible to determine the extent to which dissatisfaction with cartage rates is due to the carriers' or dealers' exclusive authority over them. It does not seem unreasonable to infer, however, that since the shipper has no voice in the selection of the service he might chafe a bit at also being deprived of the privilege of participating in the making of rates for that service.

In the market, the volume of milk handled at the various pick-up rates largely determines the significance of rate-variation as a factor in market stability. The net revenues derived from hauling operations are available for concessions which, with price discounts now illegal, may be equally satisfactory in the form of superior service; the direction taken by this effort being limited chiefly by the operator's imagination.

Cartage Rates Applicable Throughout the Milkshed

Varying amounts were paid for milk-cartage service by 973 full-time producers; sales were made to 40 dealers; shipments were made over 64 routes.

Rates apparently were set for the most part on a per quart basis with the actual rate rounded off to the nearest five-cent interval. The frequency distributions in table 9 tend to illustrate the existence of the practice. The most common rate was 35 cents per hundredweight. Occasionally the total deduction for Control Board assessments and hauling was 35 cents per hundredweight, in which event the actual trucking levy was calculated to be 33 cents.

Although rates ranged from 8 to 80 cents per hundredweight, 78.8 percent of the producers paid from 23.4 to 46.5 cents or ½ to 1 cent per quart. In the group, 34.9 percent of the producers paid from 30.1 to 35.0 cents per hundredweight or approximately ¾ cent per quart. The proportion of producers who paid more than 35 cents per hundredweight, 15.2 percent, was relatively low. Twenty-two different rates[17] were effective for this group.

Six of the 40 dealers regularly used more than one truck or carrier in collecting their supplies. (Table 10.) These handlers made purchases from 491 farmers; accounted for 30 of the routes; and altogether used 17 different rates in figuring cartage charges. On 12 out of the 30 routes, a rate of 25 cents per hundredweight was effective; on 10 of them a rate of 30 cents per hundredweight was used. The number of rates applied per route ranged from one to five. Most of the routes had only one or two rates in effect. Only four of the routes used five rates. The distribution is shown in table 11.

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[16]Due to absence of one criterion of a competitive market; that is, all sellers are not equally informed about conditions in the market.

[17]Whole numbers.

TABLE 9.—FREQUENCY DISTRIBUTION OF CARTAGE RATES APPLICABLE THROUGHOUT THE SPRINGFIELD MILKSHED, 1935
(Various Class Intervals)

Class Interval ¼c. per quart	f	Class Interval 5c. per cwt.	f	Class Interval 10c. per cwt.	f
0 – .115	5	0 – .05	0	0 – .10	3
.116 – .233	176	.051 – .10	3	.101 – .20	105
.234 – .348	334	.101 – .15	60	.201 – .30	375
.349 – .465	433	.151 – .20	45	.301 – .40	392
.466+	23	.201 – .25	183	.401 – .50	95
Unknown Rate	2	.251 – .30	192	.501+	1
		.301 – .35	340	Unknown Rate	2
Total	973	.351 – .40	52		
		.401 – .45	54	Total	973
		.451 – .50	41		
		.501+	1		
		Unknown Rate	2		
		Total	973		

TABLE 10.—DISTRIBUTION OF DEALERS ACCORDING TO THE NUMBER OF COLLECTION ROUTES SERVING THEM, 1935

Number of Routes		Number of Dealers	Number of Producers	Number of Rates
Per Dealer	Per Group			
1	34	34	482	18
2–3*	5	2	73	8
5–7*	25	4	418	14
	64	40	973	

*Combined so as to prevent identification of any individual dealer.

TABLE 11.—DISTRIBUTION OF TRUCK ROUTES ACCORDING TO NUMBER OF RATES APPLICABLE PER ROUTE

Number of Rates Applicable Per Route	Number of Routes
1	40
2	13
3	4
4	3
5 or more	4
	64

Among the handlers who used only one truck in the collection of their supplies, a great variety of rates existed. The surprising fact is perhaps that there was not even more variation. There were 34 routes in this group and only 18 different rates. A situation of this sort might suggest either the absence of any attempt to determine cartage rates based exclusively on cost, or the impossibility of so doing.

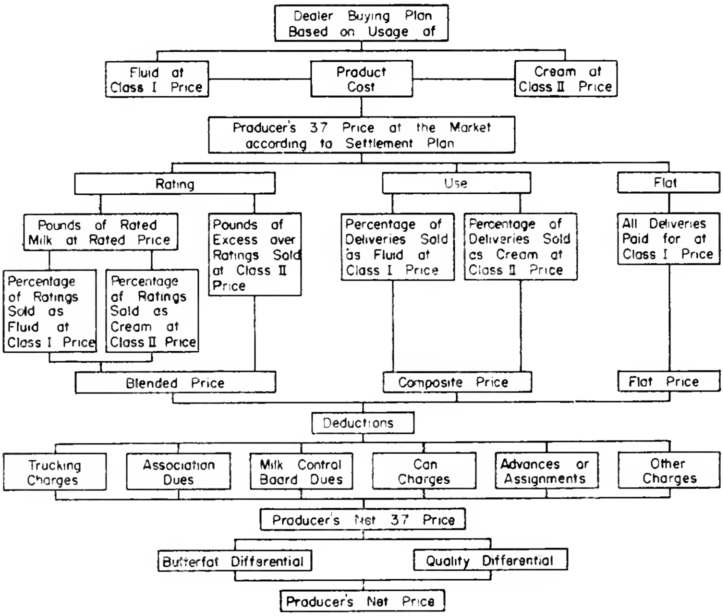

Figure 4. Schematic Diagram Showing Methods by Which Producers' Prices Are Determined

PART II

VARIATION IN PRICES RECEIVED BY DAIRYMEN

As part of the general appraisal of the Springfield milk supply, a study was made of the characteristics of prices received by farmers. The objectives were several. In the first place, it seemed desirable to systematize the prices with which farmers had to deal. Secondly, it was essential that some appraisal be made of the relative importance of price per se. Thirdly, if variation was a markedly apparent characteristic there was need of determining, so far as possible, the extent, the effect, and the probable causes of it.

The cash value at the farm per hundred pounds of milk is, in the final analysis the price in which the farmer is interested. That is the actual return per hundredweight for the product which he has to sell; from it his income is derived and out of it his expenses are met.

This assertion is not made with any intent to minimize the importance of transportation charges, market-service charges, class prices, butterfat differentials,

Acknowledgment: Mr. Alfred H. Planting, a former graduate student, assisted materially with the planning and development of this aspect of the study.

or market utilization of the product. Prices including any one of these elements, however, may present a slightly incomplete picture so far as the dairyman is actually concerned. They do, of course, at any particular point in the marketing or pricing process provide a basis for making comparisons having particular applications.

The several routes by which the farm value of milk is derived are shown in figure 4.

The importance of price may be an indeterminable matter. If a difference of 50 cents per hundredweight is reasonable and if the additional income secured thereby would have paid a grain bill or left a cash margin, then price is extremely important. Even with an example of this sort, however, it is impossible to ignore the income implication.

Of the two elements determining the income of 1174 full-time shippers, which had the greater effect on it—price or deliveries? A theoretical application of prices to the volumes actually delivered by two dairymen will serve to illustrate the magnitude of the forces involved. Extremes in price and volume have been used, in order to emphasize the relationships. First, consider the shipper who had the largest volume of deliveries. Had he received the lowest farm price in the group, his annual income would have been $3557.24 lower than it was (a reduction of 45.1 percent). Then consider the shipper having the smallest volume of sales. Had he received the highest farm price in the group, his income from milk would have been $506.06 higher (a gain of 82.0 percent).

The average shipper with annual sales of 74,000 pounds faced the possibility of a variation of over $1000 in annual income depending upon whether circumstances, mostly beyond his control, permitted him to receive the highest or the lowest price applicable in the shed. Differences of this magnitude in an industry devoted to, dependent on, and protected by the public cannot be indifferently dismissed. It is also, perhaps, well to remember that probably all shippers at some time and some shippers all the time have figured and do figure their milk checks at some price other than the one received. The potential paper losses or gains may have caused renewed pledges of appreciation or of determination. If more positive action has been lacking, despite the effect of such variation on income, it has been due to the mollifying influence of Milk Control.

Sample areas were selected as a basis for determining the geographical pattern of certain price characteristics. They were chosen so as to allow for as many probable causes of variation as possible. Area 2[18] is contiguous to the Springfield–Holyoke–Chicopee market and on the fringe of the Hartford milkshed. Area 12 is on the western fringe of the Springfield–Holyoke–Chicopee shed and somewhat isolated from any other sizable market or supply. Area 6 is on the eastern edge of the Springfield–Holyoke–Chicopee shed and is also a part of the Worcester supply.

The experience of sample groups of shippers was used in evaluating price characteristics on a dealer basis. The producers' settlement plan in the Springfield–Holyoke–Chicopee area was and is of the familiar "dealers' choice" and the effect of ratings and seasonality are more susceptible to analysis if treated in this manner. Since the larger dealers operate throughout the entire shed in the procurement of their supplies, a respresentative group of shippers was chosen from each one of them for study. Except for errors of "omission" or "commission," the records of these shippers would probably provide the widest and most varied experiences.

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[18]Figure 6.

TABLE 12.—PROPORTION OF TOTAL PURCHASES TAKEN BY FOUR DEALERS BY AREAS, 1935

Area	Purchases by Four Dealers	Purchases as Percentage of Commercial Production	Actual Price (Area Average)
1	968,283	20.1	$2.404
2	3,163,025	56.9	2.469
3	850,256	58.9	2.218
4	1,847,556	77.3	2.466
5	524,756	16.2	2.693
6	5,974,252	96.0	2.503
7	1,079,379	16.5	2.659
8	744,607	17.3	2.590
9	1,782,294	86.5	2.784
10	3,071,989	100.0	2.644
11	3,994,184	83.3	2.573
12	909,198	64.8	2.495
13	1,081,548	83.2	2.576
14	444,246	12.6	2.600
Combined areas	26,435,573*		
Milkshed	36,184,460	47.2	

*Represents 71.9 percent of the combined purchases of the four dealers.

A bird's-eye view of the actual prices received by Massachusetts shippers throughout the milkshed can be had from figures 5 and 6. Dairymen in Area 9 were apparently the best off and those in Area 3 the poorest. As would be expected an extreme comparison of that sort presents a lop-sided view of the situation. Variation existed among all the areas to be sure, but for all that there existed a tendency towards uniformity.

Uniformity might or might not be a desirable characteristic of shippers' prices, depending on the particular type of price that was being considered; e.g., F.O.B.

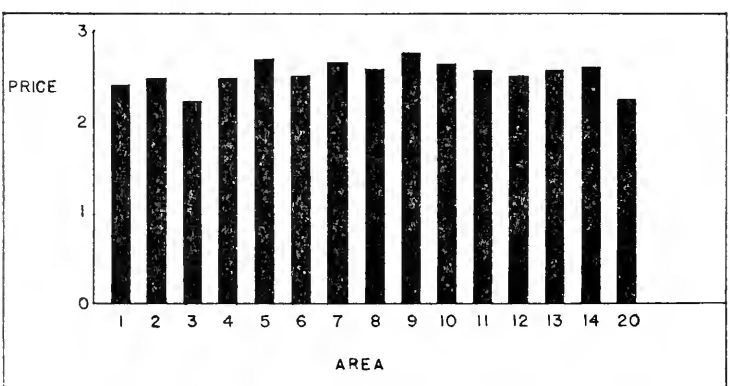

Figure 5. Average Area Price (Dollars per Hundredweight) of Milk, 1935, Actual Basis

the market, 3.7 net, actual net, etc. Uniformity of actual prices throughout a milkshed might be as much of an abnormality as variation in prices at the market. If there is objection to differences in shippers' prices, it should be directed at the degree, the incidence, and the cause.

The difference in prices among the areas was tested for statistical significance by making an analysis of variance among three sample areas. It was essential that an attempt be made to determine whether the differences were small enough to have been due to chance, or whether large enough to have been caused by forces other than chance. Tenable conclusions could be formed on the relationships among the sample areas, whereas were the analysis to be applied to all the areas the number of combinations would be so large as to be unwieldy.

A comparison of shippers' returns on a sample geographical basis brought out the relatively great amount of variation which existed within areas rather than between areas. The range in mean prices between the areas was only 19.6 cents per hundredweight. In contrast, the smallest difference between shippers' prices in any particular area was 74 cents per hundredweight found in Area 12; the greatest, 122 cents per hundredweight in Area 6. The general price situation, however, in Area 6 was more favorable to the shippers, the average being approximately 20 cents higher (19.6), the standard deviation slightly lower, and substantially more shippers being included in the modal group.

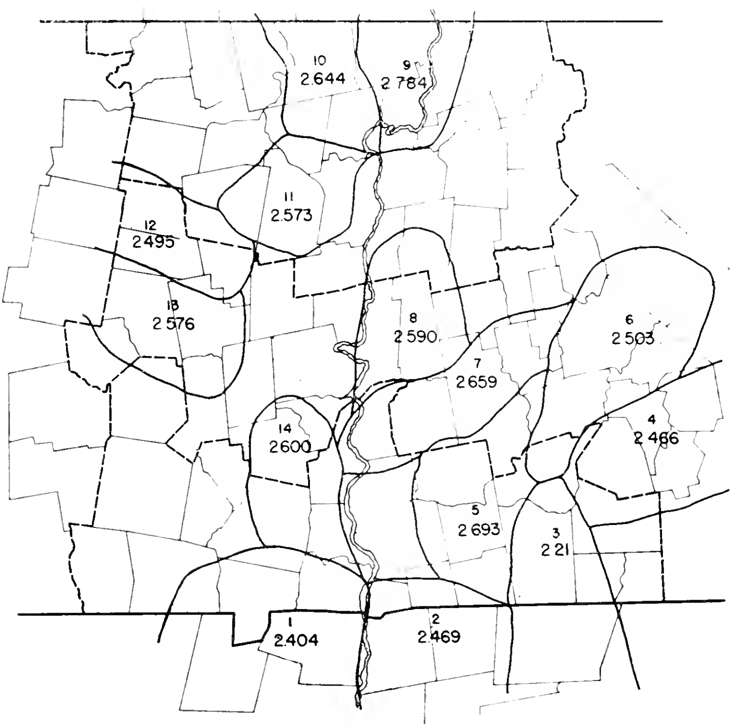

Figure 6. Average Net Prices Throughout the Springfield-Holyoke-Chicopee Milkshed, 1935, By Areas

The cause of variation in the average area price can be gleaned from table 13. The number of dealers operating in each of the areas varied and their product-costs differed noticeably—differences due mostly to variations in utilization.

TABLE 13.—AVERAGE PRICES F. O. B. MARKET FOR 3.7 PERCENT GRADE B MILK PAID BY DEALERS IN THREE SELECTED AREAS OF THE SPRINGFIELD–HOLYOKE–CHICOPEE MILKSHED IN 1935.

Dealer	Mean of prices paid for 3.7 percent milk, per hundredweight	Number of producers
	Area 2	
79	$2.23	11
52	2.50	13
70	2.64	5
67	2.81	35
60	2.86	3
61	3.24	1
78	3.26	5
59	3.26	2
		75
	Area 6	
03	2.49	10
70	2.64	8
67	2.86	47
64	2.95	3
57	3.25	3
		71
	Area 12	
03	2.44	7
70	2.54	15
25	2.83	9
		31

No definite relationship existed between area prices and physical factors. The dealers in the market who had the larger volume of business almost of necessity had to operate throughout the entire shed to secure their supplies. If they were not subject to that necessity then they had over-all operations because of other advantages. Regardless of the cause, the net result was the same. Each subdivision of the milkshed, i.e., area, represented the results of the particular combination in which the dealers were associated. Apparently distributors paying the higher price took their choice of shippers and their associates successively moved in according to the price that could be paid.

Further light on the geographical relationships between prices may be had from the data in table 14. The average price received by the shippers of each

handler in an area was compared with the mean price [19] of all the shippers to that handler to determine whether or not a tendency towards uniformity existed.

TABLE 14.—COMPARISON OF WEIGHTED AVERAGE OF PRODUCERS' 3.7 F. O. B. PRICES ADJUSTED FOR CHARGES*, WITH DEALER'S PRODUCT-COST

Dealer	Mean of Producer's 3.7 F.O.B. Prices*	Dealer's Product-Cost	Difference Between Prices
		Area 2	
79	$2.30	$2.31	−$ .01
52	2.57	—	—
70	2.71	2.71	.00
67	2.88	2.93	− .05
60	2.93	3.25	− .32
61	3.24	3.25	− .01
78	3.26	3.26	.00
59	3.26	3.26	.00
		Area 6	
03	2.56	2.57	− .01
70	2.71	2.71	.00
67	2.93	2.93	.00
64	3.02	2.71	+ .31
57	3.25	3.25	.00
		Area 12	
03	2.51	2.57	− .06
70	2.61	2.71	− .10
25	2.84	2.56	+ .28

*Adjusted, except in the case of flat-plan dealers and cooperatives, by the addition of a 6 cent charge made by the N.E.M.P.A., plus, except in the case of flat-plan dealers, a 1 cent charge for the Milk Control Board.

In most of the arrangements characterized by practically identical prices, the dealer had only a few shippers and all were located in the one area. Relationships among shipper groups selling to dealers having more than ten patrons were variable. In Area 2 three groups were involved and each handler sub-group had a mean price identical or nearly so with the milkshed average for the handler.

Except for one small group a similar relationship existed in Area 6. The shippers whose prices were substantially above average had an average ratio of ratings to deliveries of 95.8 percent. As a consequence of this rather "ideal" relationship between rating and deliveries, the average price received by this group tended to approximate that paid for rated milk rather than that paid for all milk.

The situation in Area 12 was the most variable. Each sub-group differed appreciably from the over-all average; two below and one above. Data were not complete for each of the dealers. If it were, analysis would probably show that the advantages and disadvantages, as the case might have been, were also associated with ratings.

[19]The dealer's product-cost.

The tendency for uniformity throughout the milkshed in the prices paid by any particular handler is further borne out by the analysis on a dealer basis of differences in prices received by shippers.

The pronounced variation in prices received by shippers would tend to dampen any notion that chance could have been a substantial contributory cause of the differences. On the other hand, however, one could not necessarily assume that the variations were predetermined in some clandestine fashion. One might suspect, if he were familiar with the market, that the organization of the market and the arrangements between handlers and shippers would be a basic consideration. Testing the assumptions by analysis of variance gave results which indicated a high degree of validity.

Analysis showed upon systematizing shippers' prices that—

1. Adjusting values to a comparable 3.7 percent test removed about half of the variation in the prices;
2. Adjusting next for trucking charges removed a slight amount of the remaining variation;
3. Adjusting further for seasonality had practically no effect on the variation remaining at this stage.

The effect of ratings on price depended upon whether or not the dealer planned on having the sum of his shippers' ratings approximate—

1. His sales,
2. His purchases.

When ratings approximated sales, the effect of ratings was a significant cause of variation in shippers' prices. (Table 16A.)

When ratings did not approximate sales (and therefore probably approximated purchases), ratings had no effect on variation in price. (Table 16B.)

The effect of these variables should not cloud the importance of differences in dealers' product-costs (based on use) as a major cause of differences in shippers' prices. In arriving at the effect of butterfat, trucking charges, seasonality, and ratings on shippers' prices, dealers' product-costs were held constant. The importance of dealers' product-costs as a cause of variation is well emphasized by the data in table 15.

The prices received by 1174 full-time shippers of Grade B milk were used in making the analysis of variance. The results were highly significant with each type of price used. Not only was the variation in prices on a dealer basis mathematically significant for each type, but with progressive refinement of the prices the significance of the dealer classification became increasingly pronounced.

With the variance ratio "F" 1.61 or greater, there was one chance in a hundred that differences in dealer classification were not a major cause of price variation.[20]

Since the value of "F" was 78.6 with unrefined prices, the probable importance of dealer grouping was immediately emphasized. Standardizing prices to a common 3.7 F.O.B. basis raised the value of "F" to 210.0 (Table 15). Removal of these causes of variation, by expanding "F", helped clarify and accentuate the probable influence of forces which were peculiar to dealer groups.

From an inspection of the Mean Squares in table 15 one can also draw some conclusions concerning the relative effects of butterfat test and of trucking charges on shippers' prices. The amount of variation in shippers' prices within dealer groups was reduced nearly 50 percent after adjusting the prices to a comparable

[20]Snedecor—p. 177, Table 10.2—Statistical Methods.

3.7 percent basis and only slightly more upon further adjusting for trucking charges. In other words, for the shippers selling to any given dealer the differences in butterfat are a much more significant cause of variation in the actual prices received than are differences in trucking rates.

As the amount of variation in shippers' prices within dealer groups declined with progressive refinement, the amount of variation between dealer groups increased. The mean squares between dealer groups increased slightly when prices were adjusted for butterfat and rather noticeably after further adjusting for trucking charges. This result is probably to be expected. It simply means that there are scarcely noticeable differences in the butterfat content of the purchases of milk made by dealers; that the amount of variation became slightly more pronounced when the butterfat was adjusted to a common standard of 3.7 percent.

TABLE 15.—ANALYSIS OF VARIANCE IN MILK PRICES RECEIVED BY 1174 PRODUCERS IN THE SPRINGFIELD–HOLYOKE–CHICOPEE MILKSHED IN 1935

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Significance
		Actual Net Price		
Between dealers	992,500	41	24,207	$F = 24207/308 = 78.6^{**}$
Within dealers	348,441	1,132	308	For $n_1 = 40$ and $n_2 = 1000$
Total variation	1340,941	1,173	1,143	1% $F = 1.61^{**}$
		3.7 Net Price		
Between dealers	1,084,222	41	26,447	$F = 26447/157 = 168.5$
Within dealers	177,363	1,132	157	For $n_1 = 40$ and $n_2 = 1000$
Total variation	1,261,696	1,173	1,076	1% $F = 1.61^{**}$
		3.7 F.O.B. Net Price		
Between dealers	1,334,641	41	32,552	$F = 32552/155 = 210.0$
Within dealers	175,179	1,132	155	For $n_1 = 40$ and $n_2 = 1000$
Total variation	1,509,820	1,173	1,287	1% $F = 1.61^{**}$

A comparison of the mean squares before and after adjusting for trucking charges brings out the relatively greater amount of variation in trucking charges between dealers compared to that existing within dealers.

In addition to fat, trucking charges, and dealers' product-costs, other probable causes of variation in shippers' prices could have been seasonality and the ratio of ratings to deliveries (i.e., for those shippers selling on a rating plan). Size of rating means little except when expressed in relationship to deliveries or when considered with due regard for the handlers' use of the plan. With due regard for these items, shippers to dealer A were grouped on the basis of having shipped more than their ratings or having shipped just their ratings. Shippers selling less than their ratings would be in the same price position as those having ratings and deliveries in adjustment.

Summary data are given in table 16A. The three basic shippers' prices were used in the comparison, and with each type there were highly significant differences between the group means. Differences of this size then could be caused by variation in the ratio of ratings to deliveries. Since the removal of other possible causes of variation by systematizing was associated with an expansion of "F," the significance of ratings as a cause of price differences was very pronounced.

Whereas ratings had a decided influence on the prices received by shippers selling to dealer A, they had no common effect on the prices received by the shipper to dealer B. The results of the analysis are given in table 16B. In no instance did "F" equal 1 percent or 5 percent values which would indicate ratings as a basic cause of price variation. Additional weight was afforded this conclusion by the irregular adjustments in the value of "F" as prices were systematically refined. For all practical purposes, dealer B might as well have been on the straight use plan so far as the prices to his shippers were concerned.

Seasonality of production under the conditions which prevailed in the Springfield market had no significant effect on producers' prices. The adjusted data were not subjected to any test other than that of observation. The data for all three groups, table 17, were so nearly comparable that apparently little could be gained by an extended analysis.

Frequency distributions of the prices received by grade B shippers are given in table 18. The mid-point of the modal price class was 5.5 cents per quart for both the actual and the 3.7 standardized fat basis; the mid-point of the modal price class on a 3.7 standardized F.O.B. basis was 6.25 cents per quart, indicating an average trucking charge of 35 cents per hundredweight.

A summary of the characteristics of the various types of prices is given in table 19.

TABLE 16.—STATISTICAL MEASURES OF THE EFFECT OF RATINGS

A. WHEN THE SUM OF PRODUCER'S RATINGS IS APPROXIMATELY EQUAL TO THE DEALER'S CLASS I SALES (DEALER A)
B. WHEN THE SUM OF PRODUCER'S RATINGS IS ABOUT EQUAL TO THE DEALER'S PURCHASES FROM PRODUCERS (DEALER B)

Type of Price	A. Two Groups Selling to Dealer A			B. Two Groups Selling to Dealer B		
	30 Shippers with Ratios below 90	30 Shippers with Ratios from 95 to 104	Significance of the Difference Between the Groups	21 Shippers with Ratios below 90	21 Shippers with Ratios from 95 to 104	Significance of the Difference Between the Groups
	Standard Deviation			**Standard Deviation**		
Actual Net Prices	14 232c	13.282c		21 157c	10.368c	
3.7 Net Prices	13.216c	10.108c		10.724c	11.136c	
3.7 F.O.B. Prices	9 668c	9 955c		8 852c	9 247c	
	Coefficient of Variation			**Coefficient of Variation**		
Actual Net Prices	5 855	5.167	Not significant	9 227	4 510	Highly significant
3.7 Net Prices	5.565	3.942	Not significant	4 825	4 904	Not significant
3.7 F.O.B. Prices	3.589	3 478	Not significant	3 480	3 560	Not significant
	Mean			**Mean**		
Actual Net Prices	243.07c	257.07c	Highly significant	229.29c	229 90c	Not significant
3.7 Net Prices	237.47c	256.43c	Highly significant	222.24c	227 10c	Not significant
3.7 F.O.B. Prices	269.40c	286.20c	Highly significant	254 38c	259.71c	Not significant
	Analysis of Variance			**Analysis of Variance**		
Actual Net Prices	F = 15.52**		Highly significant	F = 69.39		Not significant
3.7 Net Prices	F = 38.99**		Highly significant	F = 2 07		Not significant
3.7 F.O.B Prices	F = 43 96**		Highly significant	F = 3 65		Not significant

TABLE 17.- SUMMARY OF PRICE ANALYSIS OF TWO GROUPS OF 29 SHIPPERS HAVING A RATIO OF RATINGS TO DELIVERIES (1) OF LESS THAN 90 PERCENT; (2) OF 95-104 PERCENT.

Type of Price	(1) Group with Ratios of Less than 90 Percent			(2) Group with Ratios of 95-104 percent		
	Price Unadjusted for Seasonality	Price Adjusted for Excess Seasonality	Price Adjusted for Excess and Rated Seasonality	Price Unadjusted for Seasonality	Price Adjusted for Excess Seasonality	Price Adjusted for Excess and Rated Seasonality
	Standard Deviation			**Standard Deviation**		
Actual Net Prices	13.917c	16.815c	16.541c	13.451c	14.146c	13.599c
3.7 Net Prices	13.048c	9.012c	8.894c	10.122c	10.115c	9.703c
3.7 F.O.B. Prices	9.634c	8.067c	7.910c	10.131c	9.703c	9.320c
	Mean			**Mean**		
Actual Net Prices	242.41c	271.21c	271.10c	256.83c	265.59c	265.72c
3.7 Net Prices	236.90c	265.69c	265.59c	256.10c	264.86c	265.00c
3.7 F.O.B. Prices	269.03c	297.83c	297.72c	286.17c	294.93c	295.07c
	Coefficient of Variation			**Coefficient of Variation**		
Actual Net Prices	5.741	6.200	6.101	5.237	5.326	5.118
3.7 Net Prices	5.508	3.392	3.349	3.952	3.819	3.662
3.7 F.O.B. Prices	3.581	2.709	2.657	3.540	3.290	3.159

TABLE 18.—DISTRIBUTION OF PRICES RECEIVED BY FULL-TIME PRODUCERS OF GRADE B MILK IN THREE SELECTED AREAS OF THE SPRINGFIELD–HOLYOKE–CHICOPEE MILKSHED IN 1935

Midpoint Cents per Quart	Class Limits per Hundredweight (Dollars)	Actual Net Price					3.7 Net Price					3.7 F.O.B. Price				
		Area 2	Area 6	Area 12	Total Number	Total Percent	Area 2	Area 6	Area 12	Total Number	Total Percent	Area 2	Area 6	Area 12	Total Number	Total Percent
3.50	1.57–1.68		1		1	.56										
3.75	1.69–1.80	1			1	.56		1		1	.56					
4.	1.80–1.91	1			1	.56										
4.25	1.92–2.03	3	1	1	5	2.82	9	1	2	12	6.78					
4.50	2.04–2.15	3	3	2	8	4.52	2	4	4	10	5.64		1	1	2	1.13
4.75	2.15–2.26	7	5	1	13	7.34	6	3	7	16	9.03	10			10	5.65
5.	2.27–2.38	12	9	9	30	16.94	13	7	9	29	16.40	2	1	3	6	3.39
5.25	2.39–2.50	9	9	4	22	12.42	11	8	2	21	11.86	5	4	3	12	6.77
5.50	2.50–2.61	20	22	4	46	25.97	14	30	3	47	26.60	11	5	10	26	14.68
5.75	2.62–2.73	8	11	3	22	12.42	11	14	1	26	14.68	11	9	7	27	15.30
6.	2.73–2.84	5	8	2	15	8.47	4	3	3	10	5.64	11	13	2	26	14.68
6.25	2.85–2.96	2	1	4	7	3.95	1			1	.56	12	32	2	46	25.98
6.50	2.97–3.08	3	1		4	2.25	3			3	1.69	5	3	3	11	6.21
6.75	3.08–3.19			1	1	.56										
7.	3.20–3.31	1			1	.56	1			1	.56	8	3		11	6.21
	Totals	75	71	31	177	99.90	75	71	31	177	100.00	75	71	31	177	100.00

TABLE 19.—A COMPARISON OF PRICES RECEIVED BY SHIPPERS IN THREE SAMPLE AREAS OF THE SPRINGFIELD–HOLYOKE–CHICOPEE MILKSHED IN 1935

Price Characteristic	All Areas	Area 2	Area 6	Area 12	Range Between Areas
Actual Net Price					
Highest	$3.24	$3.24	$3.04	$3.10	$0.20
Lowest	1.64	1.78	1.64	2.03	.39
Mean	2.49	2.47	2.50	2.49	.03
Standard Deviation	.26	.28	.23	.27	.05
Modal Group* Limits	2.15 to 2.84	2.15 to 2.84	2.26 to 2.73	2.15 to 2.84	
Percentage in Modal Group	83.6%	81.3%	71.8%	74.1%	
Range within Areas	$1.60	$1.46	$1.40	$1.07	
3.7 Net Price					
Highest	$3.24	$3.24	$2.82	$2.77	$0.47
Lowest	1.70	1.92	1.70	1.92	.22
Mean	2.45	2.45	2.50	2.32	.18
Standard Deviation	.25	.28	.20	.23	.08
Modal Group* Limits	2.15 to 2.73	2.15 to 2.84	2.26 to 2.73	2.03 to 2.61	
Percentage in Modal Group	78.5%	80.0%	83.0%	80.6%	
Range within Areas	$1.54	$1.32	$1.12	$ .85	
3.7 F.O.B. Price					
Highest	$3.29	$3.29	$3.27	$3.01	$0.28
Lowest	2.05	2.19	2.05	2.27	.22
Mean	2.73	2.71	2.80	2.61	.19
Standard Deviation	.26	.30	.20	.21	.10
Modal Group* Limits	2.38 to 3.08	2.38 to 3.08	2.49 to 3.08	2.38 to 2.84	
Percentage in Modal Group	83.6%	73.3%	87.3%	70.9%	
Range within Areas	$1.24	$1.10	$1.22	$ .74	

*Established classes within which the Mean plus the Standard Deviation falls.

REVIEW

This study is the third of a series pertaining to the supply of milk for the Springfield-Holyoke-Chicopee area. The first[21] was a detailed analysis of milk hauling from one section of the milkshed to the market. The second[22] was an analysis of dealers' product-costs.

The three studies thus far completed offer some basis for making changes which it seems would improve for the farmer and for the industry the general conditions and returns from the sale of milk. Anyone familiar with milk marketing recognizes the conflicting interests of buyer and seller; of the individual and the group; of general welfare and personal power; of individual weaknesses and group strength; of individual strength and group weaknesses.

Our attitude has been one of moderation. Our feeling has been that changes should be gradual; that even though injustice exists care should be taken in eliminating it, lest it be merely shifted from one person to another.

A program of this sort is of course dependent upon a common appreciation of the problems facing the industry, a general desire for their removal, and concerted determination directed towards that end.

To date the Milk Control Board has felt that prices should be fixed F.O.B. the market. The studies indicate that a change in the policy to one of pricing F.O.B. the farm for secondary markets has much in its favor. A move of this sort is in a sense a major operation. It is one which offers the patient the possibility of a healthy existence.

Any proposed pricing technique should be examined in the light of its objective. Fortunately for most fluid markets, these objectives are fairly well stated in the legislative briefs supporting the state milk control laws. The basic assumption around which the network of milk control developed is that an adequate supply of high quality fluid milk is necessary to the public welfare. In order to assure the public an adequate supply of milk, the state and the federal governments have decided that the dairy industry, i.e., farm production, should be protected against the more undesirable aspects of competitive pricing. Accordingly, most control laws have stipulated that buyers should own their purchases of milk at the same class prices at the market. Additional refinements have been incorporated into milk control laws or regulations, but pricing on a uniform basis is generally regarded as the one principle that is indispensable. Originally uniform prices meant uniform class prices and applied to the dealers' purchases F.O.B. the market, with the result that in some milksheds there still existed under state control a noticeable variation in the blended prices received by shippers. With the development of federal orders and the introduction of the market pool, uniform prices F.O.B. the market became a reality to shippers and the uniformity of price to dealers was extended from class prices to the blended price or product-cost.

Many markets, especially the secondary intrastate ones, use the dealer-pool with prices on a class basis F.O.B. the market. Trucking, with few exceptions, is the only assembly facility needed and the arrangements for it are generally made by the dealer. The costs of getting the milk from farm to city plant are mostly met by the farmer. The costs are defrayed by charges based on rates which are set by the dealer. This sort of organization and arrangement has provided the public with an ample supply of milk and has given the farmer a dependable outlet for his farm production.

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[21]Massachusetts Agr. Exp. Station Bulletin No. 363.
[22]Massachusetts Agr. Exp. Station Bulletin No. 365.

The growth in the independent pricing of the various processes involved from the moment the milk leaves the farm until it reaches the consumer is probably a basic fault. Specific allowances for trucking, for receiving, for pasteurizing and bottling, for paper containers, for wagon delivery in place of store sales must inevitably either increase the total cost of the product to the consumer or lower the returns to the producer. A combination is possible but improbable.

Pricing milk F.O.B. the farm rather than F.O.B. the city under the conditions enumerated, i e.,

1. Direct Haul,
2. Dealer—Pool,

could improve conditions considerably. The primary objection to this method, i. e., discrimination to nearby shippers, is untenable under current conditions. Actually the present system is exceedingly unfair to the nearby producer. Handlers operating throughout several of the sheds have a single cartage rate; a few of them have several rates but only one rate is apt to apply to a particular route even though distances and volumes on any particular route vary noticeably.

There might be some objection to pricing F.O.B. the farm on the ground that such a practice would defeat one of the essentials to market stability; namely, known and uniform prices for milk having the same use. Such a deduction does not necessarily follow. It should, upon a moment's reflection, be apparent that the point in the marketing process at which prices are to be uniform should bear some relationship to the objectives sought. Because pricing F.O.B. the market seems desirable for primary markets served by common carriers having published transportation rates and a variety of applicable rates, one should not necessarily conclude that the market is the point at which uniform prices should be set for direct-haul areas. In markets characterized by a dealer-pool, product-costs vary even though class prices are uniform. In fact pricing F.O.B. the city in direct-haul areas and with a variety of trucking rates tends to defeat the instrument of control, "known and uniform prices."

With class prices set F.O.B. the farm, a number of improvements might take place. It is reasonable to assume that, if handlers are to "bear the expense" for getting their supplies to the plant, they will do it as efficiently as possible; i. e., if assembling costs are an important consideration. If other considerations are more significant, their true worth will become apparent.

Farm pricing might normally cause some adjustments that could be expected to exist in a so-called ideal situation. In markets having dealer-pools and dealers' choice of price plans, the handler settling with his producers on a flat basis is in a preferred competitive position. Handlers owning their purchases on the use-plan would find themselves ranked according to the proportion of purchases in fluid sales. Since the objective of each handler would be low aggregate costs per unit, each one would endeavor to secure his supplies as near the plant as possible; quality and volume per stop being considered. In practice, the flat plan dealers would operate in nearby territory; just beyond them dealers having a high proportion of purchases in fluid sales would be favored; and the handlers having the larger proportion of purchases in Class II would secure their supplies on the outer edge of the milkshed. This progression is certainly desirable and therefore more or less inevitable. Dairy farmers are interested in the value per hundredweight of milk sold as well as in class prices. The ability, generally speaking, of handlers to secure supplies would vary with the blended prices, which in turn depends largely on sales of Class I milk.

The flat plan dealer, having 100 percent of his purchases in fluid sales, could and would pay the top price and presumably could buy from any shipper in the shed. He might be expected to confine his operations close to the market. Gen-

erally his volume of business is not large; his size of load accordingly small, and unit transportation charges high. In order to keep aggregate costs at a minimum, he will then operate in a nearby area.

Handlers on the use-plan who have the highest ratio of fluid sales to purchases do a larger volume of business than the flat-plan dealers but considerably smaller than the average of all dealers. With a similar desire to keep aggregate costs down, they will operate their trucks in areas adjacent to and on the outer side of the flat-plan territory. Although the length of haul for this group will be greater, the larger load will keep the unit costs down.

Finally, on the outer fringe will be found the handlers with the larger volume of business. Here, also, long hauls will mean higher total transportation costs. Large loads, however, will tend to keep unit costs low so that the average cost or the class cost per hundred pounds of purchases will be kept down. From an industry point of view, these are desirable changes.

Introduction of pricing F.O.B. the farm might and probably would disturb some producer–handler arrangements. So far as the Springfield–Holyoke–Chicopee market is concerned, these changes would probably take place among the handlers buying on a flat plan and among handlers buying only a relatively small volume of milk. No immediate changes other than these would necessarily occur.

So far as handlers are concerned, the results should be generally beneficial. Advantages now enjoyed by a few would be removed and a more nearly competitive situation would exist in product-costs. The method would enable them to retain whatever benefits were inherent in an efficient collection system. They could utilize without question their truckmen as good-will men. In contrast with the rather positive effects are the unpredictable reactions. Handlers might object to pricing F.O.B. the farm on the grounds that they might have to pay the same Class prices in the country as they now pay in the city. Some might try to require producers to bring in their shipments without due allowance for the service. For the most part, however, the difficulties could be readily overcome, if the industry were sincerely interested in bringing about conditions which would be generally desirable rather than the various groups seeking individual advantages.

There is an even more significant question facing the industry than that of harmonizing the present elements. Practically all the legislation underlying state and federal control is based on the premise that an increased consumption of fluid milk is indispensable to public welfare. There has been little questioning of the premise even though some might cast doubt on its validity. Since the public seems willing, however, to accept the recommendation, the objective of milk control at least becomes specific.

A low per capita consumption of milk is caused by a number of factors; some people dislike it, some people think it isn't worth the price, and other people haven't the income to buy it at any price. For the most part, unfortunately, the limiting elements are economic and as such are not easily influenced by the recommendations of nutrition experts. If milk is indispensable to public health, the needs of the public should be determined and a program devised which would facilitate attaining that goal. If the use of milk generally is only desirable, like fruit juices, but not indispensable to the welfare of the state, then the efforts to maintain farm income and farm production should perhaps be reestablished.

People in many of the states have had sufficient experience with milk control to appreciate the necessity of clear designation of the premises underlying it. Rather superficial examination of the record would indicate that the control agencies have concentrated on maintaining the supply, overlooking, perhaps, the fact that

under some conditions consumers in exercising their free choice would not be particularly interested whether the supply were maintained or not.

As a matter of public policy the maintenance of a healthy people is of major concern. It would seem that as a matter of common sense steps necessary to the achievement of such a condition would be taken without hesitation. If one of those steps is the inclusion of a minimum quantity of fluid milk daily in the diet, a program should be devised toward that end.

Just as price has been made an inducement to production, so should it be an inducement to consumption. The consumer may be less sensitive to price than the producer, but it is a certainty that he is not insensitive.

Remunerative prices to producers and simultaneously attractive prices to consumers are incompatible under our present method of pricing and organization in the fluid milk industry. Between the producer and the consumer some services must be and many services are performed in assembling and distributing the commodity. The costs incident thereto are legitimate and amount to approximately half the retail price. In addition to absorbing this sizable proportion of the price to the consumer, the servicing costs are fairly rigid and under state control have become more so, with a tendency to increase. Adjustments in consumers' prices are reflected consequently in producers' prices and any significant revisions to consumers would be intolerable to producers.

If prices are to be sufficiently low to actively induce consumers to use more milk, the costs of servicing must be reduced. Several alternative methods of bringing this about are available to the public. The present pattern of distribution may be maintained and the cost borne by the local municipality as a subsidy in the interest of public health. The pattern of distribution may be revised along any one of numerous lines with the elimination of some services and the performance of others by the consumer himself. The most comprehensive reorganization would still recognize processing, packaging, and wholesale deliveries as essential functions; functions which might be expected to cost about two cents per quart. It seems unlikely that anything but outright public support of distribution will encourage the increase in consumption that nutritionists say is desirable. The price received by the producer would then be the price paid by the consumer, and there is the possibility that these two might be compatible.

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The Composition and Nutritive Value of Potatoes with Special Emphasis on Vitamin C

By William B. Esselen, Jr., Mary E. Lyons, and
Carl R. Fellers

Potatoes enjoy a prominent position in the American diet. It is the purpose of this study to evaluate the nutritive properties of this popular vegetable, with special emphasis on the value of the cooked potato as a source of vitamin C.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

THE COMPOSITION AND NUTRITIVE VALUE OF POTATOES WITH SPECIAL EMPHASIS ON VITAMIN C

By William B. Esselen, Jr., Assistant Research Professor, Mary E. Lyons,[1] Research Fellow, and Carl R. Fellers, Professor, Department of Horticultural Manufactures

INTRODUCTION

From colonial times potatoes have been one of the major vegetable crops and have enjoyed an important position in the American diet. Their mild flavor, which makes them an ever-pleasing part of a meal, their low cost as a source of energy, and their ease of preparation have contributed to make potatoes a daily constituent of our meals. However, most people overlook the fact that potatoes, in addition to being a pleasant tasting vegetable and an economical source of energy, possess also other important nutritive qualities. It is the purpose of this bulletin to evaluate the potato nutritionally, particularly in respect to vitamin C. In view of the present national emergency it seems particularly timely to emphasize the true value of this important food stuff.

POTATOES AS AN IMPORTANT FOOD CROP

The large food value that can be produced on a small area of land, the ease and low cost of production, and the good storage qualities of potatoes are responsible for their value as an agricultural crop. According to Stewart (45), potatoes rank first among the vegetables in quantity produced and used in the United States. Since 1906 it has been one of our largest commercial vegetable crops.

The commercial potato crop (51) for 1939 was 364,016,000 bushels which was harvested from 3,027,000 acres of land. The average yield per acre for the 10-year period 1929–1939 was 111.5 bushels. In Massachusetts alone, the commercial crop in 1939 was 2,635,000 bushels with many more grown in unreported small plots and gardens. The principal potato-producing areas are the northern and northeastern states. Although almost all of the states produce some potatoes, the most important potato-producing states are Maine, Minnesota, New York, Pennsylvania, Michigan, and Wisconsin. Aroostook County in Maine is particularly well known for its fine potatoes.

THE COMPOSITION OF POTATOES

In order to evaluate a foodstuff from the standpoint of its nutritive value it is necessary to know its chemical composition. This is approximated for the edible portion of potatoes in Table 1.

Potatoes are essentially a good source of energy because of their high carbohydrate content. For many years the evaluation of potatoes in the diet was based on this fact. Recent advances in nutrition have shown the importance of minerals and vitamins. Today foods are evaluated on a basis not only of carbohydrate, fat, and protein content but also of mineral and vitamin content. Potatoes have been found to contribute important amounts of essential minerals to

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the diet. In Table 1 it is shown that potatoes contain approximately 1 percent of ash or minerals. This important 1 percent may be further broken down and analyzed as presented in Table 2.

TABLE 1.—AVERAGE CHEMICAL COMPOSITION OF EDIBLE PORTION OF THE POTATO* (7)

Water	77.80 percent
Protein	2.00 percent
Fat	0.10 percent
Ash (minerals)	0.99 percent
Carbohydrate (starch, sugars, etc.)	19.10 percent
Fuel or energy value	385 calories per pound or 85 calories per 100 grams
Approximate potential reserve alkalinity	9.0 cc. normal alkali per 100 grams

*Additional data on the composition of potatoes and other vegetables may be found in a recent bulletin by Holland and Ritchie (20).

TABLE 2.—THE MINERAL CONTENT OF THE EDIBLE PORTION OF THE POTATO

Mineral	Percent	Authority
Calcium	0.013	41
Magnesium	0.027	41
Potassium	0.496	41
Sodium	0.024	41
Phosphorus	0.053	41
Chlorine	0.035	41
Sulfur	0.029	41
Iron	0.0011	41
Copper	0.000164	41
Manganese	0.000173	41
Nickel	trace	4
Cobalt	trace	4
Barium	trace	34
Zinc	0.0004	3
Iodine	85-226 p.p.b. of dry matter	14, 18, 33
Aluminum	0.00097	50

FACTORS INFUENCING THE COMPOSITION OF POTATOES

Fertilization, Soil, and Variety

The composition of plant material is subject to variation according to variety, soil, and fertilization. Potatoes are no different from other plant materials in this respect. Considerable work has been published dealing with the composition of potatoes as influenced by variety, soil, and growing conditions. Metzger and co-workers (35) have summarized a comprehensive study on the composition of potatoes as follows:

> Potatoes from one locality may differ significantly in starch, dry matter, protein and ash from those of another locality. Varieties may differ significantly in starch, dry matter, protein and ash. A significant difference in dry matter, protein and ash between years has also been obtained. Irrigated potatoes are higher in starch and dry matter, but lower in protein than dry-land potatoes.

It has been reported by Hayne (17), McClendon, Barrett, and Canniff (33), and Freas (14) that there is a marked variation in the iodine content of potatoes, which appears to vary with the iodine present in the soil in which they are grown. The iodine content of potatoes and other vegetables in relation to its presence in the soil is of particular interest in considering the incidence of goiter.

Storage

The temperature at which potatoes are stored has a marked effect on their relative starch and sugar content. Cool storage temperatures favor the conversion of starch to sugar in the potato tuber, and warm storage temperatures favor the reverse reaction. In a recent study Wright et al. (57) found that the sugar and starch content of potatoes stored at 50°-60° F. remained practically unchanged, whereas the sugar in potatoes stored at lower temperatures progressively increased and the starch decreased. Denny and Thornton (10) reported large differences in the amount of reducing sugar present in different varieties of potatoes both before and after storage at different temperatures. Low storage temperatures caused an increase in the reducing sugar.

In a discussion of the storage of potatoes Barmore (2) believes it probable that there are only two reactions which are responsible for their sugar content: respiration, or the oxidation of sugar to carbon dioxide and water; and second, the transformation of starch to sugar and vice versa. When the temperature of storage is reduced, respiration is retarded and this effects a shift in the starch–sugar equilibrium so that the sugar concentration is increased. At higher storage temperatures these reactions are reversed and the sugar is slowly decreased with an increase in starch.

The question of sugar content is particularly important from the standpoint of making potato chips from stored potatoes. The presence of reducing sugar is responsible for objectionable brown colors in potato chips (10), and when potatoes are to be used for this purpose, storage conditions should be controlled so as to keep the sugar content low.

THE CARBOHYDRATE, PROTEIN, AND MINERALS OF THE POTATO

Carbohydrate

As mentioned in the introduction, potatoes are generally thought of as an important source of energy. The caloric or energy value of potatoes is due almost entirely to their carbohydrate content. McCance and Lawrence (32) have reported a comprehensive investigation to distinguish between the available and unavailable carbohydrate of cooked foods. Their information is important in that it actually evaluates the available carbohydrate content of foodstuffs as they are served. The data for potatoes are summarized in Table 3. "Total Reducing Sugars" includes starch, sucrose, and other carbohydrates which may be hydrolyzed with acid to reducing sugars, as well as reducing sugars themselves. Practically all of the carbohydrate of the potato is available as a source of energy.

TABLE 3.—THE CARBOHYDRATE CONTENT OF COOKED POTATOES AS SERVED (32)

Carbohydrate Fraction	New Potatoes	Old Potatoes
	Percent	Percent
Total reducing sugars	16.1	19.9
Pentose sugars	0.2	0.37
Non-fermentable sugars	—	1.2
Available Carbohydrate	15.6	19.2

Pectin

The pectin present in the potato differs in its physical and chemical properties from that found in most fruits. The methoxyl content is low and the viscosity of aqueous solutions is less than that of fruit pectins. Potato pectin is useless in jelly making.

Some investigators have suggested that mealiness in potatoes is caused by the separation of cells brought about by the solution of pectic materials. In studies conducted at this station, Freeman and Ritchie (15) determined the pectin content of four varieties of potatoes and observed its change during storage and as a result of baking. They found that raw potatoes contained from 20.0 to 26.8 milligrams of calcium pectate per gram of dry sample. No loss in pectin occurred during six months' storage at 1.7° to 4.4° C. (35° to 40° F.). In most cases there was a small loss of pectin as a result of baking. These authors suggest that potato pectin can be adequately defined by two fractions:

> 1. A fraction that is soluble in ammonium citrate (or oxalate) and insoluble in hot water. This fraction may be pectic acid or insoluble salts of the acid.
> 2. A fraction that is easily dispersed by hot water but not by cold water. Since this fraction is so easily removed, it is possible that it is not the postulated cellulose-pectin complex of protopectin but rather a lyophilic gel that is readily peptized by warm water.

They conclude:

> Analyses of water-soluble pectin fractions of raw and cooked potatoes offer additional evidence that the solution or degradation of pectic material does not determine mealiness in potatoes.

Protein

The protein of the potato is chiefly a plant globulin known as tuberin (24). The potato is not an important source of protein because it contains only a small amount and even that is of relatively low biological value. Potato protein is 78 percent digestible and has a biological value of 67 and a protein value as a food of 0.8 (36).

The White House Conference of 1932 (54) suggested that sources of protein be grouped according to the percentage of the total calories that presumably should be provided by them if these proteins are to be the only ones in the diet. On this basis potatoes rate as a fair source, providing 12–20 percent of the total calories. However, the proteins are adequate for maintenance but not for growth.

Minerals

In addition to being a good source of energy, potatoes are an important source of certain essential minerals. The ash of potatoes is particularly rich in potassium and contains significant amounts of many of the other minerals (Table 2). In evaluating potatoes on the basis of minerals furnished, one must consider the relatively large amounts of this vegetable usually included in the diet as well as the actual composition of the ash per se.

Potatoes are considered one of the cheapest sources of iron and an economical source of calcium (46). They also contain significant amounts of iodine in many instances, depending upon where they are grown (17).

In order for a foodstuff to be of value as a source of minerals they must be present not only in significant amounts, but also in a form that can be utilized by the body. This is particularly necessary in the case of iron. Many of the vegetables known to contain appreciable amounts of iron cannot be considered good sources of this element because it is not available. In potatoes the iron is almost 100 percent available (43).

THE VITAMIN CONTENT OF POTATOES

During the past ten years many studies have been made of the vitamin content of potatoes, particularly vitamin C. Potatoes have been found to be a good source of vitamins B_1 and C. They also contain measurable amounts of the other vitamins. The vitamin content of potatoes is subject to variation according to variety, length of storage, and growing conditions. In a general consideration of potatoes as a source of vitamins in the diet, it is necessary to deal with average values which have been determined by many workers. These values represent the amount of vitamins that the consumer can expect to be present in potatoes. In Table 4 potatoes are evaluated as to their vitamin content.

TABLE 4.—VITAMIN CONTENT OF POTATOES PER 100 GRAMS EDIBLE PORTION

Vitamin A	30-50 international units (41)
Vitamin B_1 (Thiamin)	95-165 micrograms (41)
Vitamin B_2 (Riboflavin)	40-80 micrograms (41)
Vitamin C (Ascorbic Acid)	7-15 milligrams (41)
Pantothenic Acid	650 micrograms (23)
Vitamin B_6 (Pyridoxine)	40 rat units (40)
Vitamin K	small amount (9)
Biotin	small amount (25)

STUDIES OF THE VITAMIN C CONTENT OF POTATOES

The present investigation was conducted to determine the vitamin C content of Massachusetts potatoes in comparison with potatoes grown in other sections of the country. Differences in vitamin C content due to variety, storage, and cooking were observed. A preliminary report on this investigation has been made by Lyons and Fellers (29).

Differences in the vitamin C content of different varieties of potatoes have been reported by Smith and Paterson (44), Mayfield, Richardson, Davis, and Andes (31), Ijdo (22), and Wachholder and Nehring (52). Fixsen and Roscoe (13) have summarized the available data on varietal difference. Up to 10 percent variation

in ascorbic acid content between individual potatoes within the same variety has been found by Ijdo (22). Effects of cooking on the ascorbic acid content vary from a gain (Richardon, Davis, and Mayfield, 37), and a very slight loss (Thiessen, 48; Armentano, 1; and Levy, 27) for potatoes boiled in the skins, to a large loss for baked or fried potatoes (Levy, 27). Ijdo (22) reported that the amount of ascorbic acid present is but little affected by the locality of production, and is independent of tuber size; that there is uniform distribution throughout the potato; and that there is practically no oxidized ascorbic acid present. Høygaard and Rasmussen (21) found that the addition of 1 percent sodium chloride to the cooking water increased the retention of ascorbic acid. Thiessen (48), Mayfield, et al. (31), Smith and Paterson (44), and Zilva and Barker (58), found a decrease in ascorbic acid after storage. Woods (56) states that new immature potatoes contain twice as much vitamin C as mature potatoes, and that common storage of the mature potato for three to eight months does not change the vitamin C content to any marked degree.

Methods

The method of Tillmans, Hirsch, and Hirsch (49), as modified by Bessey and King (5) and Mack and Tressler (30), was used for the determination of ascorbic acid in potato tubers. Twice normal sulfuric acid and 2 percent metaphosphoric acid were used in the extraction of the potatoes. The method of Buck and Ritchie (6) was used to standardize the 2,6-dichlorophenolindophenol dye solution.

At the start of this investigation the accuracy of the dye titration method for determining vitamin C in potatoes was checked against the biological method. Raw, baked, and boiled potatoes were assayed for vitamin C using the guinea pig method of Sherman, LaMer, and Campbell (42) as modified by Eddy (12). The results of the two methods were in close agreement in all cases, thus indicating the accuracy of the chemical test for this purpose. For example, 4.5 grams of raw potatoes or 5.3 grams of boiled potatoes had an antiscorbutic value in the guinea pig assay of 0.5 milligrams of ascorbic acid, that is 10 international units of vitamin C (28). When these same samples of potatoes were examined by the indophenol titration procedure, identical values were obtained. Hence, throughout this investigation the dye-titration method was used.

Eight varieties of potatoes, which were grown under similar conditions on experimental plots at the Massachusetts Agricultural Experiment Station, were used. These were compared with identical varieties obtained from several other state agricultural experiment stations very soon after harvest. All of the Massachusetts potatoes were dug at the same time the first part of October.

Dehydroascorbic Acid in Potatoes

Since an oxidized, but still physiologically active form of ascorbic acid, called dehydroascorbic acid, is sometimes present in plant tissues, eight samples of raw potatoes were treated with hydrogen sulfide for 30 minutes after extraction in order to reduce any oxidized ascorbic acid which might be present. This was followed by a two-hour treatment with carbon dioxide to remove all traces of hydrogen sulfide. An ascorbic acid value of 0.20 milligram per gram, both before and after this treatment, indicated that there was no dehydroascorbic acid present in the raw potato. These findings are in agreement with those of Ijdo (22) and Rolf (39).

Wolf (55), in a study of the distribution of vitamin C in potatoes, concluded that the outer tissues are 8 to 46 percent richer in total ascorbic acid than the inner, but that in the skin 19 to 55 percent of the total is dehydroascorbic acid. In the inner part only 0 to 20 percent of the total ascorbic acid was in the dehydro form.

Table 5.—Effect of Geographical Origin of Potatoes on Their Ascorbic Acid Content

Variety and Source	Ascorbic Acid—mg. per gm. Average for 8 Tubers	Ascorbic Acid—mg. per gm. Average for Variety
Irish Cobbler		0.131
Massachusetts	0.157	
California	0.122	
Virginia*	0.059	
Kentucky	0.200	
Maine	0.072	
New York	0.107	
Rural Russet		0.110
Massachusetts	0.161	
Idaho	0.062	
New York	0.108	
Katahdin		0.125
Massachusetts	0.120	
New York	0.155	
Maine	0.101	
Green Mountain		0.117
Massachusetts	0.132	
Maine	0.095	
New York	0.136	
California	0.107	
Chippewa		0.097
New York	0.099	
Massachusetts	0.096	
Triumph		
Idaho	0.132	
Louisiana**	0.051	
White Rose		
California	0.121	
Virginia*	0.073	

*In storage 2 months before being shipped—not considered in average.
**In storage 5 months before being shipped.

Effect of Variety and Origin

The results of the tests on the vitamin C content of different varieties of Massachusetts potatoes and a comparison of these with potatoes from other states are presented in Table 5. The ascorbic acid content of the same variety grown in different geographical areas was not significantly different. The general average shows that the Irish Cobbler variety was highest; Katahdin, second; Green Mountain, third; and Chippewa lowest. In general, it cannot be said that potatoes from any particular region were either high or low in ascorbic acid content. In many cases, differences between varieties were less than differences within a single variety.

Effect of Storage

Eight varieties of Massachusetts potatoes were held in storage for five months. One set of each variety was kept in cold storage at 36° F. (2.2° C.). A second set was kept in a dry, underground storage where the temperature was controlled by climatic conditions and averaged 40°-50° F. (4.4°-10° C.). This would be similar to cellar, or common, storage on a farm. The effect of these storage conditions on the ascorbic acid content of potatoes is presented in Table 6.

In two varieties the ascorbic acid content of the potatoes was higher in cold storage than in common storage; in four varieties the reverse was true; and in two varieties there was no difference. However, in every case the tubers held in cold storage were more desirable for eating purposes.

Storage seemed to cause a leveling off of the differences between varieties in ascorbic acid content. For instance, in October, freshly dug Houma potatoes contained 0.104 milligrams per gram more ascorbic acid than Warba potatoes dug at the same time. After five months of storage the difference in ascorbic acid content of these two varieties was only 0.032 milligrams per gram.

TABLE 6.—EFFECT OF FIVE MONTHS IN STORAGE ON ASCORBIC ACID CONTENT OF EIGHT VARIETIES OF MASSACHUSETTS-GROWN POTATOES
Cold storage, 36° F. (2.2° C.); common storage, 40°-50° F. (4.4°-10° C.)

Variety	Ascorbic Acid*—mg. per gm.			Loss due to Storage—percent	
	October 1938 When Dug	March 1939 Cold Storage	March 1939 Common Storage	Cold Storage	Common Storage
Green Mountain	0.167	0.114	0.120	31	28
Katahdin	0.120	0.130	0.117	0	2.5
Chippewa	0.181	0.085	0.066	53	63
Irish Cobbler	0.157	0.078	0.107	50	32
Houma	0.250	0.099	0.093	60	63
Warba	0.146	0.067	0.088	54	40
Russet	0.161	0.087	0.110	47	31.5
Golden	0.131	0.079	0.072	39.5	45.0

*Mean value of 8 different tubers of each variety.

Distribution of Vitamin C in the Potato Tuber

Three separate sets of tests were made to study the distribution of ascorbic acid within potatoes. Raw, boiled, and baked potatoes were used. The results are presented in Table 7. There was an even distribution of ascorbic acid in the raw tuber itself, with a lesser amount in the skin. In boiled potatoes there was a greater amount of ascorbic acid in the area between the central and epidermal portions. The skin and the part just beneath it were about equal in ascorbic acid content. With baked potatoes, the skin and the pulp adhering to it were considered the epidermal portion. The concentration of ascorbic acid was greatest in the central portion of the baked potatoes with the amount decreasing progressively toward the skin.

TABLE 7.—DISTRIBUTION OF ASCORBIC ACID IN THE FLESH OF RAW, BOILED, AND BAKED POTATOES

Potato No.	Ascorbic Acid—mg. per gm. Central Portion (18% of whole)	Medial Portion (55% of whole)	Epidermal Portion (20% of whole)	Skin (7% of whole)
		Raw Green Mountain Potatoes		
1	0.129	0.120	0.115	0.071
2	0.134	0.124	0.138	0.117
3	0.120	0.129	0.128	0.107
4	0.136	0.134	0.134	0.098
5	0.147	0.147	0.152	0.135
6	0.120	0.124	0.138	0.099
Mean	0.131	0.129	0.134	0.104
		Boiled Green Mountain Potatoes		
1	0.055	0.046	0.023	0.029
2	0.018	0.055	0.032	0.029
3	0.050	0.032	0.027	0.029
4	0.050	0.039	0.042	0.047
5	0.059	0.072	0.046	0.047
6	0.064	0.064	0.054	0.047
Mean	0.049	0.051	0.037	0.038
		Baked Irish Cobbler Potatoes		
1	0.203	0.149	0.130	—
2	0.140	0.110	0.080	—
3	0.210	0.120	0.073	—
4	0.130	0.126	0.063	—
5	0.102	0.073	0.084	—
6	0.100	0.105	0.097	—
7	0.089	0.110	0.073	—
8	0.150	0.120	0.110	—
Mean	0.140	0.114	0.086	—

The above findings show that, whereas in the raw potato the ascorbic acid is evenly distributed, during the cooking process something happens to change this distribution. Possibly the outer part of the potato, which is in direct contact with the heating medium, maintains a higher temperature throughout the cooking process than the inner portion. This probably results in a greater destruction of the ascorbic acid in the epidermal portions and greater retention in the center. Also, in the case of boiled potatoes some ascorbic acid is lost through the leaching action of the cooking water.

Relation of Size of Tuber to its Ascorbic Acid Content

Both large and small mature raw tubers of the Green Mountain variety grown on experiment station plots were carefully examined for ascorbic acid content. Marked variations existed in both small and large tubers, but there was no correlation between the ascorbic acid content and the size of the tubers.

The Effect of Cooking on the Ascorbic Acid Content of Potatoes

Baking and Boiling

Baked potatoes have long been considered preferable to boiled potatoes because of their better retention of water-soluble minerals and vitamins. As ascorbic acid is water soluble it seemed as though baking would be the ideal method of cooking to retain the maximum antiscorbutic value of the tuber. In order to investigate this point eight varieties of potatoes were both baked and boiled in the customary manner. The boiled potatoes were cooked whole in the skin in water containing 1 percent salt. From Table 8 it may be seen that, contrary to expectations, there was in general less loss of vitamin C in boiled potatoes than in baked potatoes. Baked potatoes showed an average loss of 49 percent

TABLE 8.—EFFECT OF VARIETY AND COOKING METHODS ON THE VITAMIN C CONTENT OF POTATOES
(Eight tubers tested for each value)

Variety	Ascorbic Acid—mg. per gm.			Loss—percent	
	Raw	Baked	Boiled Whole in Skin*	Baked	Boiled Whole in Skin*
Katahdin	0.110	0.108	0.080	2	27
Chippewa	0.181	0.096	0.086	45	53
Houma	0.250	0.085	0.165	66	34
Irish Cobbler	0.157	0.064	0.083	59	47
Golden	0.131	0.061	0.061	53	53
Warba	0.146	0.071	0.101	51	31
Green Mountain	0.132	0.069	0.113	48	14
Russet	0.161	0.094	0.102	42	37
Average	0.158	0.081	0.099	49	37

*Boiled in water containing 1 percent salt.

of their ascorbic acid as compared to a 37 percent loss for boiled potatoes. Rolf (39) has also reported a slightly greater loss of ascorbic acid in baked than in boiled potatoes.

Boiling in Salted and Unsalted Water

According to Lanman and Minton (26), the texture and the flavor of vegetables are improved if salt is added to the water during the cooking process rather than after it has been completed. In this work six potatoes were tested before and after boiling in salted and unsalted water. After a 25-gram portion had been removed horizontally across the center to determine the ascorbic acid content of the raw potato, one-half of the tuber was placed in boiling water containing 1 percent salt and the other half in boiling unsalted water. As may be seen in Table 9 the percentage of ascorbic acid lost varied with the individual tuber. However, there was a 4 percent difference between the average percentage of retention of ascorbic acid in favor of the salted water. These findings are in agreement with those of Høygaard and Rasmussen (21) who found that the addition of 1 percent sodium chloride to the cooking water of potatoes appeared to aid in the retention of their ascorbic acid.

TABLE 9.—LOSSES OF ASCORBIC ACID DUE TO BOILING GREEN MOUNTAIN POTATOES IN UNSALTED OR SALTED WATER

Potato No.	Ascorbic Acid—mg. per gm.			Loss—percent	
	Raw	Boiled in Unsalted Water	Boiled in Salted Walter	Boiled in Unsalted Water	Boiled in Salted Water
1	0.126*	0.050*	0.059*	63.1	53.1
2	0.092	0.050	0.055	45.6	40.2
3	0.092	0.050	0.050	45.6	45.6
4	0.099	0.050	0.055	49.4	33.3
5	0.120	0.055	0.059	54.1	50.8
6	0.099	0.050	0.055	49.4	33.3
Mean	0.104	0.051	0.055	51.0	47.1

*The same tuber was used for each test of a series.

Various Common Methods of Cooking

Further tests were conducted on the effect of cooking on the vitamin C content of potatoes. These tests included various methods of preparing potatoes that are commonly used in the home such as frying, mashing, and holding boiled potatoes overnight in a refrigerator to be used in potato dishes the following day. These data are all summarized in Table 10. All values are based on an average of approximately eight tubers. The values obtained in this investigation are generally lower than those reported in a similar study by Richardson, Davis, and Mayfield (37). This difference may be accounted for by the fact that the potatoes used in this study had been in cold storage for six months as compared with thirty days' storage in the case of the above authors. It is felt that the data obtained

in the present study represent average conservative figures which may be used in evaluating the potato nutritionally throughout the winter.

All methods of cooking caused some destruction of the ascorbic acid of potatoes. The amount of destruction, which varied with the cooking method, ranged from 31 to 80 percent. It appears that the speed with which the internal temperature is raised, which in turn determines the activity of the oxidizing enzymes, may be a controlling factor. Boiling whole in the skin, baking, and French frying appear to be the best methods of cooking potatoes from the standpoint of vitamin C retention.

TABLE 10.—EFFECT OF VARIOUS COOKING METHODS ON VITAMIN C CONTENT OF POTATOES*

Cooking Method	Ascorbic Acid	Loss of Ascorbic Acid	Vitamin C in an Average Serving (5 1/4 ounces)	
	Mg. per gm.	Percent	Mg.	I.U.**
Raw	0.100	—	14.88	297
Baked	0.069	31	10.26	205
Boiled whole, salted water	0.073	27	10.86	217
Boiled peeled, cut in half	0.053	47	7.88	157
Boiled peeled, sliced	0.040	60	5.95	119
Boiled peeled, salted water	0.055	45	8.18	163
Boiled peeled, unsalted water	0.051	49	7.58	151
Boiled whole, salted water; held 24 hours in refrigerator	0.026	74	3.86	77
Boiled, salted water, mashed	0.046	54	6.84	137
Boiled, unsalted water, mashed	0.031	69	4.61	92
Boiled, creamed	0.020	80	2.97	59
Boiled, fried	0.021	79	3.12	62
Scalloped	0.036	64	5.35	107
French-fried	0.067	33	9.96	199
Boiled whole, cold—salad	0.026	74	3.86	77

*The Green Mountain potatoes used had been stored at 38° F. for 180 days.
**International Units.

In the fall and early winter approximately one fourth of man's daily requirement of ascorbic acid can be obtained from one average serving of boiled, baked, or French-fried potatoes. In the spring it would be necessary to eat approximately one and two thirds average servings to obtain the same amount of vitamin C. The daily requirement of vitamin C for an adult is estimated at approximately 75 milligrams of ascorbic acid or 1500 international units (46). Warmed-over potatoes and potato salad contained so little ascorbic acid that they cannot be considered a source of vitamin C.

Tests have recently been conducted at this laboratory[1] on the effect of refrigerator storage on the vitamin C and moisture content of foods. The foods

[1]McConnell, J. E. W., and Fellers, C. R. Mass. State College. Personal communication, 1942.

were stored in covered and uncovered dishes in home electric refrigerators at a temperature of 40°-42° F. After two days mashed potatoes had lost 40 percent of their vitamin C in covered dishes and 50 percent in uncovered dishes. After four days they had lost 90 percent of their vitamin C in both covered and uncovered dishes. The loss of moisture was negligible in covered dishes and increased regularly with the length of storage in uncovered dishes. These results indicate the advisability of keeping mashed potatoes and other vegetables in covered dishes when stored in a refrigerator in order to conserve their vitamin C and to prevent them from drying out.

Other Effects of Cooking on Potatoes

Weibull (53) found no appreciable loss of minerals and solids when white potatoes were cooked in the peel, but there was a definite loss when potatoes were peeled before boiling. Griebel and Miermeister (16) conducted similar experiments on boiling and steaming whole and peeled potatoes. The smallest loss in mineral matter occurred in the steaming of whole potatoes. The losses in total mineral matter were:—from steaming, whole potatoes 1.4 and peeled potatoes 7.1; from boiling, whole potatoes 5.8 and peeled potatoes 17.0 percent. When peeled potatoes were boiled in salted water the mineral loss was reduced to about 10 percent. Hill (19) reported that in discarding the water in which peeled potatoes are cooked about 70 percent of the minerals and antiscorbutic constituents were lost. These losses of water-soluble constituents of the potato during cooking are due to the leaching action of the cooking water. For this reason it is to be recommended that potatoes be boiled or steamed with their skins on, baked, or fried in order to prevent an excessive loss of minerals.

In discussing physicochemical changes produced by the cooking of potatoes, Sweetman (47) reported that cooking is characterized by partial gelatinization of the starch, solution of some of the pectin substance, increased digestibility of the cellulose, coagulation of most of the protein, and more or less caramelization of the sugar.

Diemair (11) reported that the flavor of baked or roasted foods is largely due to the formation of histidine bases from the decomposition of proteins. With baked potatoes the optimum temperature for the formation of these flavoring constituents was 175° C. (347° F.)

THE PLACE OF POTATOES IN THE AMERICAN DIET

From the above discussion on the composition and nutritive value of potatoes it is evident that they are a particularly good source of certain of the essential nutritive elements of the diet. This is particularly true in the case of low-cost diets where potatoes enjoy a prominent position. Potatoes are primarily important as a source of energy, vitamin B_1, vitamin C, and iron. Their low cost and the relatively large amount eaten make potatoes a very economical source of these elements.

In classifying winter vegetables as sources of vitamin C, Richardson and Mayfield (38) consider stored potatoes which have been boiled as a good source. One average serving contained 10 milligrams of ascorbic acid.

According to Stiebeling and Clark (46), the percentage of total specified nutrients contributed to the diet by potatoes when 5 percent of the food money was spent for them, based on families of city workers, East North Central region, spring 1936, is:

	Percent
Calories	13.9
Protein	10.5
Calcium	8.4
Iron	28.4
Vitamin B_1	35.0
Vitamin B_2 (G)	17.5
Vitamin C	53.9

They consider potatoes one of the cheapest sources of iron, vitamin B_1, and vitamin C; one of the next cheapest sources of calories, protein, and vitamin B_2 (G); and an economical source of calcium. Potatoes, which were formerly considered only as a pleasant-flavored vegetable included in most menus, are of very definite importance to the nutritional well-being of the individual.

In Table 11 the amount of nutrients supplied by an average serving of potatoes is presented. Many people doing active physical work or on low-cost dietaries would ordinarily include at least two servings of potatoes in their daily meals. Potatoes are very good sources of vitamins B_1 and C and of iron, for one serving supplies over 10 percent of the daily requirement of these nutrients.

TABLE 11.—AMOUNT OF NUTRIENTS SUPPLIED BY ONE AVERAGE SERVING OF POTATOES (5¼ ounces or 150 grams)

Nutrient	Daily Requirement*	Amount Supplied In One Serving	Percent of Daily Requirement In One Serving
Energy	3000 calories	127.5 calories	4.2
Protein	70 grams	3.0 grams	4.3
Calcium	0.8 gram	0.019 gram	2.4
Iron	12 milligrams	1.65 milligrams	13.7
Vitamin B_1	1.8 milligrams	0.195 milligram	10.8
Vitamin B_2 (G)	2.7 milligrams	0.090 milligram	3.3
Vitamin C	75 milligrams	10 milligrams	13.3

*Man (70 Kg.), moderately active. Recommended daily allowance for specific nutrients, Committee on Foods and Nutrition, National Research Council. (8).

SUMMARY AND CONCLUSIONS

It is the purpose of this bulletin to analyze the published information on the composition and nutritive value of potatoes and make it available in a convenient form for the use of nutritionists, home economists, extension workers, and other interested persons. In addition, research work carried on in this department on the vitamin C content of potatoes is reported.

Potatoes should enjoy an important place in the diet because they are good sources of vitamins B_1 and C and of iron. Furthermore, they can be considered a very economical source of these nutrients and of energy. Most important of all, perhaps, potatoes possess a pleasing flavor and are eaten with relish by almost everybody. They lend themselves well to the culinary arts and can be prepared for the table in many attractive ways.

The vitamin C content of potatoes seemed to be dependent upon variety. The amount of this vitamin contained in one variety of potatoes bore the same relationship to that contained in other varieties whether the samples under consideration were from a single geographical region or a composite from several states. In general, there was no significant difference in the vitamin C content of the same variety of potato grown in widely separated states in the United States. Varietal differences became less significant during storage. Common and cold storage for 6 months caused the loss of from 16 to 50 percent of the ascorbic acid of potatoes. Boiling potatoes whole and unpeeled in salted water, steaming, baking, and French-frying provided the best methods of cooking potatoes insofar as retention of vitamin C is concerned.

All methods of cooking potatoes caused some destruction of ascorbic acid. The amount destroyed varied from 33 to 80 percent, depending upon the method of cooking used.

Nutritionists are in general agreement that many American diets are low in some important nutrients, including those of which potatoes are good sources. For this reason the generous use of potatoes is to be recommended, particularly because of their low cost. During the present emergency every effort is being made to improve the health of the nation and to economize on all things, including foodstuffs. It would thus seem that potatoes have a definite role to play in our state and national nutrition program.

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A Survey and Study of Spontaneous Neoplastic Diseases in Chickens

By Carl Olson, Jr., and K. L. Bullis

Neoplastic diseases (tumors) cause much loss to the poultry industry. This collection of cases of neoplasia gives information of the characteristics and relative incidence of the different types.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

A SURVEY AND STUDY OF SPONTANEOUS NEOPLASTIC DISEASES IN CHICKENS

By Carl Olson, Jr.,[1] Research Professor, and K. L. Bullis, Assistant Research Professor of Veterinary Science

CONTENTS

INTRODUCTION

Neoplastic diseases among animals take their greatest toll from the domestic chicken, where they represent a serious economic problem. This fact has led to the development of many research programs seeking a solution to the problem. A number of types of neoplasia may occur in the chicken, although it is generally recognized that those involving the cells of the lymphoid system are the more common and, therefore, the more serious to the poultry industry. Such recognition, however, tends to overemphasize the importance of the lymphoid type of tumor and to minimize the significance of the other tumors. Even though the other types are relatively infrequent in chickens, they should not be disregarded, because as a group they are responsible for a share of the loss. Another important reason why all types of tumors should be considered is the problem of differential diagnosis. Modern science is devoting much time and energy to the study of the causes, cure, and prevention of neoplastic diseases in animals, as well as in man. The study of spontaneous cases of neoplastic diseases in chickens is an important phase which has perhaps suffered from lack of attention and careful investigation. The usual practice of investigators has been to collect and describe a group of cases dealing with a specific neoplastic disease. Such data do not give information on the relative frequency of different types of tumors in chickens. The reports of Schneider (29) and Curtis (3) provide some information on the general incidence of neoplasia, but they lack details as to the specific types of disease encountered. Eber and Malke (4) have reported on 371 cases of neoplasia found in 11,903 chickens submitted to the University of Leipzig for examination over a period of 32 years. In the survey made by Goss (11) on six flocks of chickens totaling approximately 24,000 were 1446 tumors. The majority of tumors (991) were classified as "leucotic" tumors and no attempt was made to further subdivide this large group into cases of lymphocytoma, leukosis, myelocytoma, etc.

[1]The authors wish to acknowledge the aid of other members of the Department of Veterinary Science in various phases of this study, particularly Drs. J. B. Lentz and H. Van Roekel, Mr. O. S. Flint, and Miss M. K. Clarke.

Cases of tumors have been collected here for a period of several years. This accumulation has now reached a size sufficient to merit collective study and constitutes the basis for this bulletin. This study may be expected to contribute to the knowledge of the morphological characteristics of the various types of neoplasia as well as to provide information on the relative incidence of the specific types. No attempt is made to provide a comprehensive review of the literature since this was adequately done by Heim (12), with reports up to about 1930.

SOURCE OF MATERIAL AND METHODS

The cases of tumor were derived from three general sources. The principal source was the laboratory of the Poultry Disease Control Service maintained at the Massachusetts State College. Commercial poultry flocks of Massachusetts submit chickens suspected of disease to this laboratory for examination and diagnosis. During a two-year period from December 1, 1937, to December 1, 1939, all specimens received by the diagnostic laboratory and suspected of neoplastic diseases at the time of necropsy were examined histologically. Those cases found to be neoplastic were included in Collection A. A second source of material was a flock of chickens maintained at the college by the Department of Poultry Husbandry for genetic study. Some of the chickens that became ill or died were submitted for examination, and cases of neoplasia observed between December 1, 1937, and December 1, 1940, were included in Collection B. A third source of material (Collection C) consists of cases of neoplasia collected at random from various sources, such as cases found in birds serving as controls for experimental work and cases studied prior to December 1937 on which adequate information was available.[2]

A tentative diagnosis of the neoplasm was made at the time of necropsy in the majority of cases. These diagnoses were later correlated with the final diagnosis, which was arrived at with the aid of histological examination. This was done in an effort to determine the accuracy of a diagnosis made as a result of a gross examination only. This phase of the work should be of importance to those doing diagnostic work who have neither the time nor the facilities for histological study of material submitted to them for diagnosis.

Chickens suspected of neoplasia at the time of necropsy were carefully examined and sections of organs involved or suspected of involvement were prepared for histological examination. Smears of the blood were prepared when possible from chickens suspected of a blood dyscrasia. The routine procedure for histological examination was to use a hemotoxylin and eosin stain of formalin-fixed material. Special methods were used in some instances when required to establish a diagnosis.

A study of neoplastic diseases must necessarily have a scheme for naming and classifying the various forms of tumor encountered. In this connection much use was made of the standard books dealing with oncology. The works of Ewing (5), Feldman (7), and Jackson (13), particularly, have been of invaluable assistance in this respect and they, together with the contributions of other investigators mentioned in the text of this article, have served as guides for the study of the tumors encountered in chickens. The scheme of classification adopted is presented in Table 1. In general it follows the commonly used, simple scheme of classifying tumors according to the tissue from which they are derived. In the schematic classification are listed only those varieties of neoplasia which

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[2]The authors are indebted to Dr. W. A. Hagan, New York State Veterinary College, Ithaca, N. Y., for permission to use certain material collected while one of them (C.O.) was associated with that institution.

were found in the group of cases studied. Other varieties found in the chicken by others could be readily fitted into the general scheme as outlined.

TABLE 1. — SCHEMATIC CLASSIFICATION OF NEOPLASMS FOUND IN CHICKENS.

I. Tumors of hemoblastic origin.
- A. Lymphocytoma
- B. Myelocytoma
- C. Leukosis

II. Tumors of connective tissue
- A. Benign
  1. Fibroma
  2. Myxoma
- B. Malignant
  1. Fibrosarcoma
  2. Fibrochondrosarcoma
  3. Osteochondrosarcoma
  4. Histiocytic sarcoma
- C. Special forms of connective tissue tumors
  1. Neurogenic sarcoma

III. Tumors of epithelial tissue (Epithelioblastoma)
- A. Benign
  1. Papilloma
  2. Adenoma
     - a. Hepatoma
     - b. Cholangioma
- B. Malignant
  1. Adenocarcinoma
  2. Carcinoma
- C. Special forms of epithelial tumors
  1. Thymoma

IV. Tumors forming blood and lymph spaces
- A. Hemangioma
- B. Lymphangioma

V. Tumors of muscle tissue (Myoblastoma)
- A. Leiomyoma
- B. Rhabdomyoma

VI. Tumors of serous membranes
- A. Mesothelioma

VII. Tumors of pigmented tissue
- A. Melanoma

VIII. Mixed Tumors
- A. Embryonal nephroma
- B. Carcinosarcoma
- C. Teratoma

Despite the apparent simplicity of such a classification certain difficulties arise. For example, thymoma has been placed under the general heading of "Tumors of epithelial tissue" and might with equal justification be placed in the group of connective tissue tumors or in the group of mixed tumors. In general the terminology is that commonly accepted for the various types of neoplasia, although

some exceptions will be apparent upon examination of the list. The terms "neurogenic sarcoma" and "carcinosarcoma" are specific examples and their use is discussed in the sections dealing with those tumors.

Some discrepancy may be noted in the relative space allotted for the description and discussion of the different types of neoplasms. Justification for this apparent overemphasis of certain types of less common tumors may be sought in the fact that the study has added relatively more to our fund of information concerning these particular types.

DESCRIPTION OF SPECIFIC FORMS OF NEOPLASIA OBSERVED

Lymphocytoma

Comments and Classification

More than half (213) of the cases in the collection fell into the classification of lymphocytoma. Such a high frequency for this type of tumor in chickens is not surprising. Despite the fact that lymphocytoma is such a common form of neoplasia, however, there has been no satisfactory method or criterion offered for separating the different manifestations of the disease. Some cases are associated with lesions of the nervous system; some cases have a diffuse distribution of the neoplastic lymphoid cells; and in other cases the foci of neoplasia are nodular.

For the purpose of study, the cases of lymphocytoma were separated into groups with particular emphasis on the characteristic behavior of the neoplastic tissue as observed from both gross and microscopic examination. Minute cytological details such as the size of the lymphoid cells, the ratio between size of nucleus and size of cell, and the relative number of mitotic figures were not considered in the subdivision of the lymphocytomas although these features were taken into account at the time the individual cases were designated as lymphocytoma. The degree of involvement of the various organs or tissues was classified in four grades at the time of histological examination. In Grade 1 the tumor was confined to a few areas; in Grade 2, there were several areas of neoplasia; in Grade 3, a moderate amount of parenchyma was replaced by tumor cells; and in Grade 4, the majority of parenchyma of an organ or tissue was overgrown or displaced by the tumor. Classification of degree of involvement of such tissues as the musculature, skin and subcutis, and peritoneum was based on the local invasiveness at the site of the tumor. Such a procedure is not necessarily recommended for routine classification of lymphocytomas.

A preliminary survey indicated that the lymphocytomas could be separated on the basis of their morphological characters into six groups according to the following scheme:

Those with nerve tissue involved

1. Diffuse lymphocytoma
2. Nodular lymphocytoma
3. Combined diffuse and nodular lymphocytoma

Those with no nerve tissue involved

4. Diffuse lymphocytoma
5. Nodular lymphocytoma
6. Combined diffuse and nodular lymphocytoma

Diffuse Lymphocytoma.—The common characteristic of the group classified as diffuse lymphocytoma was a diffuse infiltration of the involved organ or tissues with neoplastic lymphoid cells (Plate II, Figures 1, 2, 3; Plate III, Figure 1). The majority of the lymphocytomas (118 cases) were of this type. In 51 cases

nerves, as well as other tissues, were infiltrated with lymphoid cells (Plate III, Figure 2 and Table 2). The gross appearance of organs affected with diffuse lymphocytoma varied with the extent of infiltration. When the organs were severely affected, they were enlarged and the normal color was interspersed with the gray-white of tumor tissue. In some instances the organ was almost completely replaced by tumor and the color was then gray-white. Occasionally the foci of tumor were localized and had irregular indiscrete margins. Some organs showed infiltrations upon histological examination when there was no evidence of tumor from the gross examination (Plate II, Figure 1).

TABLE 2.—CLASSIFICATION OF 213 CASES OF LYMPHOCYTOMA.

Form of Tumor	No Nerves Involved	Nerves Involved	Total
Diffuse	67	51	118
Nodular	18	2	20
Diffuse and Nodular	45	30	75
Total	130	83	213

Nodular Lymphocytoma.—The group of nodular lymphocytomas comprises those cases in which the neoplastic lymphoid tissue was in the form of nodules more or less encapsulated by a wall of connective tissue (Plate II, Figures 2, 4, 5; Plate III, Figures 3, 4). Only 20 cases of nodular lymphocytoma were found; in 2, the process also involved nerve tissue. The nodular character of the tumor was usually apparent from gross observation, although in some instances what was suspected to be a diffuse lymphocytoma was found to be nodular upon histological examination (Plate II, Figure 2). Generally the nodular arrangement was more pronounced in the liver and spleen than in other sites.

Diffuse and Nodular Lymphocytoma.—Cases of lymphocytoma in which the neoplastic tissue had characteristics of both diffuse and nodular forms were fairly common (75 instances among the series of 213 lymphocytomas). In some cases the organs were affected with both forms of neoplastic infiltration, and in other cases one form of tumor was found in some organs and the other form was found in other organs. The gross appearance of organs and tissues of the cases included in this group was a combination of the appearance of organs affected with diffuse lymphocytoma or nodular lymphocytoma (Plate II, Figure 2. Although actually nodular lymphocytoma, the process in the liver resembles the combined diffuse and nodular form).

Characteristic Features

The six groups of cases were studied by comparison with each other to find an explanation for the different manifestations characteristic of each group. Although the data do not provide clear-cut results, some things are suggested which lead to interesting speculation.

Age at Necropsy.—The youngest chicken found to be affected with lymphocytoma was a 6-week-old female which was killed for examination and found to have a Grade 4 diffuse lymphocytoma of the ovary and a Grade 1 nodular tumor of the spleen. The oldest bird found to be affected was a 104-week-old female that had a diffuse lymphocytoma infiltrating the lumbar and ischiadic nerves and adjacent musculature on one side. The average age of the 114 birds killed

for examination was 32.8 weeks, and most of these were moribund. Birds with lymphocytoma involving nerves were significantly younger when killed (Table 3). This is no doubt due to the fact that birds with nerve involvement showed symptoms (caused by the nerve lesions) earlier than birds with no nerve involvement, and the chickens were submitted for examination because of the symptoms. There was no significant difference between the six groups in age of birds that died (Table 3).

TABLE 3.—AGE OF BIRDS AT NECROPSY IN 213 CASES OF LYMPHOCYTOMA.

Age is expressed in weeks with standard error of the mean. Figures in parentheses are number of cases in group.

Form of Tumor	Died — Age in Weeks		Killed — Age in Weeks	
	No Nerves Involved	Nerves Involved	No Nerves Involved	Nerves Involved
Diffuse	36.7 ± 2.6 (44)	36.2 ± 7.6 (12)	39.4 ± 3.4 (23)	29.4 ± 2.0 (39)
Nodular	36.6 ± 5.1 (8)	32 (1)	41.5 ± 3.8 (10)	23 (1)
Diffuse and Nodular	35.8 ± 4.2 (23)	31.2 ± 5.1 (11)	33.9 ± 3.6 (22)	26.8 ± 2.7 (19)

Sex.—The effect which the factor of sex may have on lymphocytoma is somewhat difficult to determine from the data. There were 193 females and 20 males represented in the 213 cases, which is a ratio of 9.7 to 1. A similar ratio of 9.7 to 1 existed in the 118 cases of diffuse lymphocytoma; but the ratio dropped to 4 to 1 in the 20 cases of nodular lymphocytoma and increased to 14 to 1 in the 75 cases of combined diffuse and nodular lymphocytoma. There was a slight and perhaps insignificant difference in the sex ratios of the cases of lymphocytoma with nerve infiltration and those without involvement of nerves. The ratios were 12.8 to 1 (83 cases) and 8.3 to 1 (130 cases), respectively. These results suggest that a male is more apt to have the nodular form of the disease than a female and that a female is more apt to have the diffuse and nodular form of the disease than a male. The incidence of lymphocytoma in male and female chickens is covered more fully under incidence in sexes in the general discussion.

Seasonal Occurrence.—More cases of lymphocytoma were encountered during the first and last quarters of the year than during the second and third quarters (Table 4). Such frequency of incidence during these periods must be correlated with the ages of the birds as the majority of chickens in commercial poultry plants would be about 35 weeks old during the first and fourth quarters of a year. This subject is covered in more detail in the discussion on incidence of neoplasia. An interesting feature was the shift of high incidence of lymphocytoma in which nerves were involved from the fourth to the third quarter. This fact must also be correlated with the observation that such cases occurred in birds slightly younger than those in which no nerves are affected. When all 83 cases of lymphocytoma with involvement of nerves are considered, there were two peaks of high incidence, these being in the first and third quarters of the year. This finding has not been explained. The various types of lymphocytoma (diffuse, nodular, and diffuse and nodular) were essentially similar with respect to their incidence in the different quarters of the year.

TABLE 4.—LYMPHOCYTOMA: CORRELATION OF QUARTER OF YEAR AT NECROPSY AND TYPE OF DISEASE.

Figures represent percent of cases occurring in the respective quarters of the year. Figures in parentheses are number of cases in the group.

Form of Tumor	No Nerves Involved				Nerves Involved				Total			
	1*	2	3	4	1	2	3	4	1	2	3	4
Diffuse	23.9 (16)	22.4 (15)	25.4 (17)	28.3 (19)	33.3 (17)	11.7 (6)	27.5 (14)	27.5 (14)	28.0 (33)	17.8 (21)	26.2 (31)	28.0 (33)
Nodular	33.3 (6)	22.2 (4)	16.6 (3)	27.9 (5)	— —	— —	50.0 (1)	50.0 (1)	30.0 (6)	20.0 (4)	20.0 (4)	30.0 (6)
Diffuse and Nodular	35.5 (16)	8.9 (4)	6.7 (3)	48.9 (22)	30.0 (9)	16.6 (5)	36.8 (11)	16.6 (5)	33.3 (25)	12.0 (9)	18.7 (14)	36.0 (27)
Total	29.2 (38)	17.7 (23)	17.7 (23)	35.4 (46)	31.4 (26)	13.2 (11)	31.4 (26)	24.0 (20)	30.0 (64)	16.0 (34)	23.0 (49)	31.0 (66)

*1 indicates first quarter of year including months of January, February, and March. 2 indicates the following three months; and so on for 3 and 4.

Distribution of Lesions. In the group of cases studied, lymphocytoma was found to affect nearly every organ or tissue in the chicken. The order in frequency of involvement was as follows: liver, gonad, kidney, spleen, nerve, peritoneum, adrenal, intestine, marrow, lung, pancreas, heart, bursa of Fabricius, proventriculus, skeletal musculature, skin and subcutis, thymus, thyroid, parathyroid, and oviduct (Table 5).

The arrangement of lymphocytomas into groups according to type led to interesting results in connection with the distribution of lesions. The tumor, when nodular in form, was found to be confined to fewer organs and to affect certain organs more frequently than others. In the 20 cases of nodular lymphocytoma, the liver was involved in 18 (90 percent) and the spleen in 17 (85 percent). The kidney, gonad, lung, thymus, adrenal, intestine, and proventriculus were more frequently affected in cases of combined diffuse and nodular lymphocytoma than in the other forms of the disease. The marrow, peritoneum, skin and subcutis, musculature, heart, pancreas, and bursa of Fabricius were involved about as often in the diffuse type of lymphocytoma as in the combined diffuse and nodular form. (Chart 1.)

Certain differences in the frequency of organ involvement were apparent between those cases in which nerves were also affected and those in which nerves were not affected. The liver, spleen, kidney, marrow, and bursa of Fabricius were more frequently affected in those cases of lymphocytoma with no nerve infiltration. The lung, peritoneum, skin and subcutis, musculature, adrenal, heart, and proventriculus were more commonly affected when nerves were infiltrated. In some instances (liver, spleen, and adrenal) the difference was marked. Essentially similar differences were noted when the respective types of lymphocytoma with and without nerve involvement were compared as when the entire group of cases was separated on the basis of infiltration of nerves only and compared as is done in Tables 5 and 6.

The nerve tissue most commonly involved with lymphocytoma was that in the region of the anterior mesenteric plexus. Other sites frequently infiltrated with the tumor are listed in Table 5.

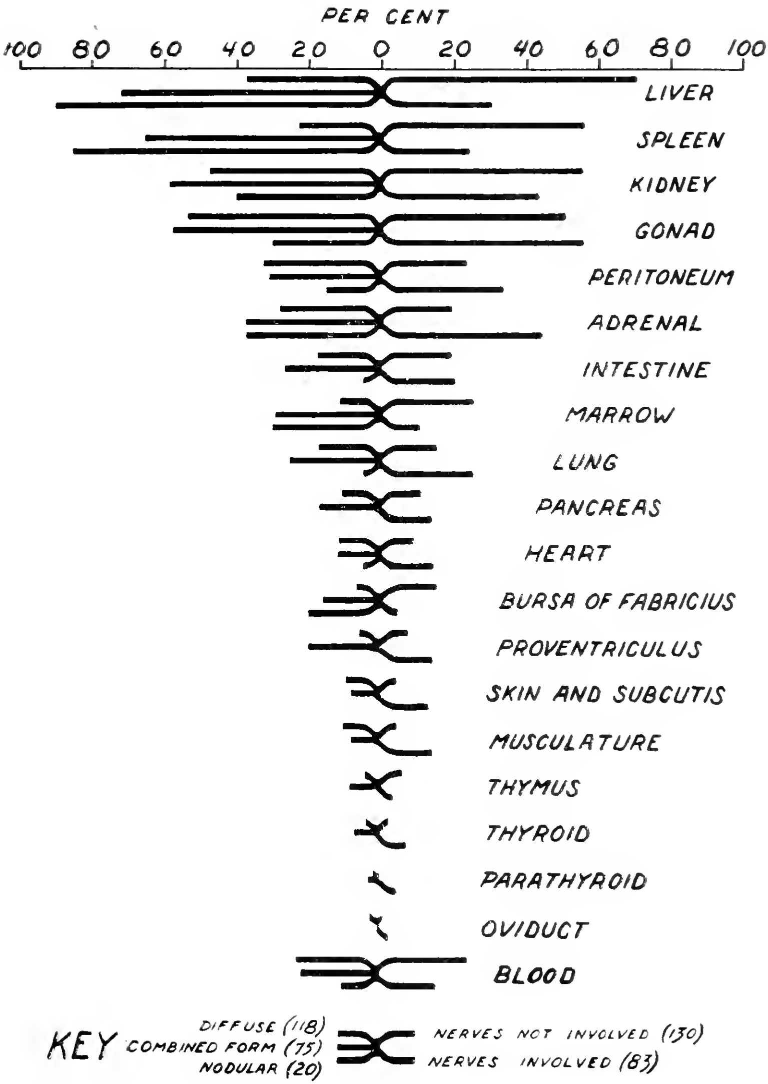

Chart 1. The Relative Frequency of Organ Involvement in 213 Cases of Lymphocytoma. The cases are listed twice: on the right-hand side, on the basis of nerve involvement; and on the left-hand side, on the basis of form of disease. The number of cases in each classification is indicated in parenthesis in the key.

Table 5.—Frequency of Organ Involvement with Lymphocytoma.

Figures represent percent of cases in which the respective organs or tissues were involved. Cases are grouped twice: according to form of tumor and on the basis of nerve involvement. Figures in parentheses are number of cases in group.

Organs or Tissues Involved	Form of Tumor			Nerve Involvement		Total (213)
	Diffuse (118)	Nodular (20)	Diffuse and Nodular (75)	No Nerves Involved (130)	Nerves Involved (83)	
Liver	37.3	90.0	72.0	70.7	30.1	54.5
Spleen	22.9	85.0	65.5	56.1	24.1	43.6
Kidney	47.5	40.0	58.7	55.4	43.4	50.7
Gonad	53.4	30.0	57.4	50.8	55.5	52.5
Marrow	11.9	30.0	29.3	25.4	10.8	19.7
Lung	17.8	5.0	25.3	15.4	25.3	19.3
Peritoneum	32.2	15.0	30.7	23.8	33.8	30.0
Skin and Subcutis	9.3	—	8.0	4.6	13.3	8.0
Musculature	10.2	—	8.0	4.6	14.5	8.4
Thymus	4.2	—	8.0	6.1	3.6	5.2
Adrenal	28.0	5.0	37.4	19.2	44.6	29.1
Heart	11.9	5.0	12.0	9.2	14.5	11.3
Pancreas	11.0	—	17.3	10.7	14.5	12.2
Intestine	17.8	5.0	26.7	19.2	20.5	19.7
Bursa of Fabricius	6.7	20.0	16.0	15.4	4.8	11.3
Proventriculus	5.9	—	20.0	7.7	14.5	10.3
Thyroid	3.4	—	6.7	2.3	7.2	4.7
Parathyroid	1.7	—	2.7	—	4.8	1.9
Oviduct	2.5	—	—	.8	2.4	1.4
Blood	22.9	10.0	21.4	24.6	15.7	21.1
Nerves—						
Anterior mesenteric	—	—	—	—	60.2	23.4
Brachial	—	—	—	—	56.6	22.0
Lumbar	—	—	—	—	51.8	20.2
Ischiadic	—	—	—	—	27.8	10.8
Vagus	—	—	—	—	27.8	10.8
of Remak	—	—	—	—	24.1	9.4

The disease was found to involve more organs or tissues when diffuse or nodular and diffuse in character. Nodular lymphocytoma was usually confined to few organs (Table 6). Lymphocytoma was confined to only four or less organs (exclusive of the various nerves and blood) in 61.9 percent of the 213 cases studied. The extent of lymphocytoma was about the same irrespective of whether or not nerves were involved, when the nerve tissue itself was left out of consideration.

The different combinations of organs or tissues that might be affected with lymphocytoma were studied. In this study involved nerves and blood were excluded. Actually 152 such combinations were found. As mentioned above, the liver, spleen, kidney, and gonad were the organs most frequently affected with lymphocytoma, and there were only 28 of the 213 cases in which none of these four organs was involved. Of these 28 cases, 25 were diffuse lymphocytoma (representing 21.2 percent of the group of 118 cases of diffuse lymphocytoma)

and the other 3 were of the combined diffuse and nodular form (4 percent of the group of 75 cases of combined diffuse and nodular lymphocytoma). In 31 cases of lymphocytoma, one organ only was involved with tumor. Lymphocytoma was confined to the ovary in 10 cases, the peritoneum in 5 cases, the liver in 3, musculature in 3, the spleen in 2, the kidney in 2, the lung in 2, the bursa of Fabricius in 2, the skin and subcutis in 1, and the adrenal in 1. Single-organ involvement with lymphocytoma was distributed among the forms of disease as follows: diffuse, 24 cases; nodular, 4 cases; and diffuse and nodular, 3 cases. In 14 cases, lymphocytoma was distributed in one of two combinations: liver, spleen, kidney, gonad, and marrow (7 cases); and liver, spleen, and kidney (7 cases). The next most frequent combination was liver and spleen only (5 cases).

TABLE 6.—NUMBER OF ORGANS OR TISSUES INVOLVED WITH LYMPHOCYTOMA

Figures represent percent of cases with the respective number of organs or tissues involved. Cases are grouped twice: according to form of tumor and on the basis of nerve involvement. Figures in parentheses are number of cases in group.

Number of Organs or Tissues Involved*	Form of Tumor			Nerve Involvement		
	Diffuse (118)	Nodular (20)	Diffuse and Nodular (75)	No Nerves Involved (130)	Nerves Involved (83)	Total (213)
1	20.3	20.0	4.0	13.1	16.9	14.5
2	17.0	15.0	17.3	13.8	21.7	16.9
3	18.6	20.0	8.0	16.1	13.3	15.0
4	17.0	20.0	12.0	16.2	14.5	15.5
5	14.4	15.0	21.4	20.8	10.8	16.9
6	7.6	5.0	9.3	7.7	8.4	8.0
7	2.5	5.0	14.7	6.9	7.2	7.1
8	1.7	—	5.3	2.3	3.6	2.8
9	.9	—	4.0	2.3	1.2	1.9
10	—	—	2.7	—	2.4	.9
11	—	—	—	—	—	—
12	—	—	—	—	—	—
13	—	—	1.3	.8	—	.5

*Organs or tissues considered are those listed in Table 5, with the exception of the various nerves and the blood.

Degree of Involvement.—In over half of the cases where either the gonad, skin and subcutis, musculature, or bursa of Fabricius was affected with lymphocytoma, the degree of involvement of these structures was Grade 4 (Table 7). Organs less severely infiltrated were the liver, spleen, kidney, lung, peritoneum, pancreas, and intestine, although in over half of the cases in which they were affected the degree of involvement of these tissues was classified as either Grade 3 or Grade 4. The marrow, thymus, and proventriculus were not often severely involved, as more than half of the cases in which they were affected were of either Grade 1 or Grade 2. The 64 cases in which the adrenal was involved were distributed almost equally in each of the four grades. Nerve tissue when affected usually had a Grade 3 involvement. The blood was considered to be affected when cells similar to those of the tumor were found in the blood of the vessels. This condition was different from the leukemic state found in fowl leukosis. The blood when involved usually fell into the classification of Grade 1 or 2.

TABLE 7.—DEGREE OF INVOLVEMENT OF ORGANS AND TISSUES IN 213 CASES OF LYMPHOCYTOMA.

Figures express percent of affected organs or tissues having the respective degree of involvement. Figures in parentheses are the number of cases in which the organs or tissues were affected with lymphocytoma.

Organs or Tissues Involved	Number of Cases	Degree of Involvement*			
		Grade 1	Grade 2	Grade 3	Grade 4
Liver	(116)	9	16	27	48
Spleen	(93)	23	21	28	28
Kidney	(108)	21	26	35	18
Gonad	(112)	5	11	16	68
Marrow	(42)	35	24	17	24
Lung	(41)	15	22	39	24
Peritoneum	(64)	13	23	22	42
Skin and Subcutis	(17)		6	29	65
Musculature	(18)	17	11	17	55
Thymus	(11)	27	27	19	27
Adrenal	(62)	24	24	28	24
Heart	(24)	[illegible]	17	53	13
Pancreas	(26)	8	12	38	42
Intestine	(42)	14	19	28	39
Bursa of Fabricius	(24)	—	—	13	87
Proventriculus	(22)	14	41	31	14
Blood	(45)	44	40	16	—
Nerves					
Anterior mesenteric	(50)	24	16	30	30
Brachial	(47)	21	11	30	38
Lumbar	(43)	12	16	47	25
Ischiadic	(23)	—	13	44	43
Vagus	(23)	4	17	48	31
of Remak	(20)	5	20	45	30

*Graded from 1 to 4, with Grade 1 representing a small amount of tumor and Grade 4 heavy infiltration.

Estimation of the degree of involvement of the blood was difficult to make and subject to considerable error. The recognition of a neoplastic lymphoid cell in the blood stream represents a problem in itself. Most of the observations on the condition of the blood were made by noting the blood contained in the vascular bed of the sections of tissue at the time of histological examination. The presence of lymphoid cells resembling those found in areas of lymphocytoma in the lumen of blood vessels was taken to represent involvement of the blood stream. In some instances actual erosion of a vessel wall located within a mass of tumor was found and obviously such an erosion would permit a mechanical washing of tumor cells into the circulation. It was necessary to exercise considerable care in some cases to distinguish between a leukocytosis of heterophils or lymphocytes and abnormal numbers of tumor cells in the blood.

There were only slight differences in the degree of involvement of the different forms of lymphocytoma (Table 8). Grade 4 involvement was noted more frequently in cases of nodular lymphocytoma and least often in the combined diffuse

TABLE 8.—DEGREE OF INVOLVEMENT IN 213 CASES OF LYMPHOCYTOMA

Figures represent percent of affected organs or tissues having the respective degree of involvement. Cases are grouped twice: according to form of tumor and on the basis of nerve involvement.

	Number of Organs and Tissues Involved*	Degree of Involvement**			
		Grade 1	Grade 2	Grade 3	Grade 4
Form of Tumor					
Diffuse	387	12.9	16.5	26.9	43.7
Nodular	66	18.2	19.7	15.1	47.0
Diffuse and Nodular	369	16.8	21.7	29.8	31.7
Nerve Involvement					
No nerves involved	517	15.2	17.4	27.8	39.5
Nerves involved	305	15.1	22.0	26.2	36.7
Total	822	15.1	19.1	27.2	38.5

*Affected nerves and blood not included.

**Graded from 1 to 4, with Grade 1 representing a small amount of tumor and Grade 4 heavy infiltration.

TABLE 9.—WEIGHT OF ORGANS AFFECTED WITH LYMPHOCYTOMA.

Mean weights expressed as percent of body weight, with standard error of the mean. Figures in parentheses indicate number of observations in group.

	Mean Weight as Percent of Body Weight			
	Liver	Spleen	Kidney	Ovary
Form of Tumor				
Diffuse	12.46 ± .92 (27)	.71 ± .06 (21)	1.19 ± .14 (43)	1.48 ± .40 (17)
Nodular	10.61 ± .94 (11)	.65 ± .23 (7)	.85 ± .12 (10)	.70 ± .15 (4)
Diffuse and Nodular	9.75 ± 1.20 (27)	.89 ± .29 (21)	.79 ± .06 (36)	.94 ± .27 (8)
Nerve Involvement				
No nerves involved	11.82 ± .68 (53)	.83 ± .15 (41)	.93 ± .09 (60)	.97 ± .28 (19)
Nerves involved	7.68 ± 1.22 (12)	.51 ± .12 (8)	1.12 ± .22 (29)	1.69 ± .45 (10)
Total	11.02 ± .64 (65)	.78 ± .13 (49)	.99 ± .08 (89)	1.22 ± .25 (29)
Organs not affected with Lymphocytoma	3.80 ± .40 (9)	.30 ± .05 (11)	.35 ± .01 (5)	.46 ± .21 (4)

and nodular form of the disease. Practically no difference was noted in the various grades of involvement between the group of lymphocytomas in which nerve tissue was affected and the group in which the nerves were free of tumor.

The organs of some of the cases of lymphocytoma were weighed at the time of necropsy. The weights of the organs most commonly found affected with lymphocytoma are listed in Table 9. They are expressed as percentage of carcass weight so that comparisons may be made between the different groups. No attempt was made to distinguish between the weight of organs with different degrees of involvement, although those with Grade 4 infiltration were usually heavier than those with less infiltration. The relative number of different grades included in the various groups is approximately comparable. In a few instances weights were obtained on unaffected organs of birds with lymphocytoma. These are indicated in Table 9 and serve for comparison with weights of affected organs. The standard error of the mean was calculated for each group. The mean values for the liver, kidney, and ovary when affected with diffuse lymphocytoma were larger than when they were affected with either of the other two forms of lymphocytoma. In the case of the spleen, the differences were not significant. A comparison of the group with nerves affected and the group with nerves not affected indicates a smaller liver and spleen and a larger kidney and ovary in cases in which the nerves were also involved, but only in the case of the liver was the difference statistically significant.

Egg Production.—Data on the egg production of chickens that developed lymphocytoma were available for only 15 cases (Table 10). These data are meager yet they suggest certain features on which more information is needed. All of these cases came from one flock on which careful records were kept. The productive life, that is, the interval between the first and last egg produced, varied from 3 to 333 days (average, 104 days). During this time the birds laid from 2 to 176 eggs (average, 60 eggs). The productive index as used is an arbitrary value obtained by dividing the number of eggs laid by the productive life in days. This factor varied from 0.074 to 0.863 and averaged 0.584. A similar production index was calculated from the records of the flock in which these cases were found. Inasmuch as the average productive life of the diseased birds was the first 108 days of production, a comparable set of figures was obtained from the flock records. The production of the flock during the first 150 days of the laying period averaged 80 eggs per hen, which provides a production index of 0.534 that may be compared with the findings in the cases of lymphocytoma. Ten of the hens with lymphocytoma had laid 25 or more eggs before developing the disease; and of these, eight had a production index higher and two a production index lower than the average for the flock. These results, compared with the slightly higher average production index for the group that developed lymphocytoma suggest that those hens which developed the disease were average to good producers.

Another point of interest in connection with egg production was the interval between cessation of egg laying and necropsy. It seems obvious that the presence of a disease condition such as lymphocytoma would have an effect on egg production. It is generally recognized that many acute diseases of chickens, such as respiratory infections, will cause a sudden decrease or cessation of egg production. The interval between the last egg laid and necropsy of a case of lymphocytoma may give some indication of the duration of the disease. In the cases reported, this period was relatively short, averaging 38 days and ranging from 4 to 73 days (in eight of the cases the interval was from 30 to 40 days). The extremely short interval of 4 days noted in Case T 1743 may have been due to the fact that the tumor of the bursa of Fabricius caused sufficient obstruction to preclude laying

of an egg, as a misshapen egg was found in the oviduct. The period between the last egg laid and necropsy did not seem to be affected either by the type or by the extent of the disease.

TABLE 10.—DATA ON EGG PRODUCTION OF CHICKENS WITH LYMPHOCYTOMA.

Productive life is the interval between first and last eggs laid. Production index is the factor obtained by dividing the number of eggs laid by the productive life in days.

Case No.	Age at Necropsy (Days)	Productive Life (Days)	Number of Eggs Laid	Production Index	Interval from Last Egg to Necropsy (Days)	Organs Affected and Degree of Involvement
			Form of Tumor—Diffuse			
T 35	[†]K 314	47	28	.596	29	Liver 4, intestine 4
T 66	D 480	210	116	.552	73	Peritoneum 4
T 169	D 316	3	2	.667	44	Ovary 3, heart 3, marrow 3
T 246	K 550	333	173	.520	44	Skin and subcutis 4
T 1743	D 409	204	176	.863	4	Bursa of Fabricius 4
T 117	K 315	108	8	.074	13	Ovary 4, liver 2, kidney 2, lung 3, adrenal 2, peritoneum 1, nerve in 4 sites
T 158	K 306	86	63	.734	33	Ovary 4, peritoneum 4, adrenal 4, pancreas 3, intestine 2, nerve in 2 sites
			Form of Tumor—Nodular			
T 2104	D 370	108	67	.620	40	Liver 4, spleen 4, kidney 2, marrow 1
			Form of Tumor—Diffuse and Nodular			
T 1175	D 454	122	89	.730	21	Liver 1, kidney 1, peritoneum 1, Bursa of Fabricius 4
T 124	K 253	34	16	.470	40	Liver 3, kidney 4, marrow 2, adrenal 1
T 43	K 345	79	52	.659	47	Liver 4, spleen 3, kidney 3
T 168	D 338	129	43	.333	35	Ovary 4, kidney 4, adrenal 4, musculature 3, heart 3, lung 2, spleen 1
T 145	K 268	31	21	.678	34	Ovary 3, skin and subcutis 4, thymus 4, adrenals 2, peritoneum 2, lung 3, proventriculus 2, intestine 4, spleen 1, kidney 1, one nerve
T 155	K 269	28	19	.679	71	Liver 3, peritoneum 4, one nerve
T 64	D 313	45	26	.578	30	Liver 3, lungs 3, peritoneum 4, adrenal 2, proventriculus 1, one nerve
Average	340	104	60	.584	38	Four organs per case

[†]K indicates that bird was killed for examination; D, that it died.

Discussion

Deposits of neoplastic lymphoid tissue in nerves of chickens are the subject of controversy as to whether they represent foci of lymphocytoma or are a part of the disease known as fowl paralysis. A consideration of this controversy naturally leads to the question of whether or not a distinction should be drawn between fowl paralysis and lymphocytoma. In other words should each of these conditions be considered as a separate entity? During the last fifteen years this subject has been argued pro and con. The results of attempts at experimental transmission of the conditions have not led to a conclusive answer. The results and conclusions as set forth in the excellent monograph on fowl paralysis by Pappenheimer, Dunn, and Cone (24) published in 1926 are most modern and are

comparable with more recent results obtained by experiments indicating a transmissible character for fowl paralysis and a possible etiological relation with lymphocytoma. Opposed to the results indicating experimental transmission of fowl paralysis are experiments of other investigators who obtained negative results.

The present study, being confined to observations on pathological anatomy of lymphocytoma, does not permit conclusions on questions concerning etiology. Deductions, therefore, must be considered in this light without regard to the results of transmission experiments.

The pathology of the nerve lesions seen in fowl paralysis has been described as both inflammatory and neoplastic in character. The inflammatory lesions consist of an infiltration with polyblasts (lymphocytes, histiocytes, and plasma cells), oftentimes associated with a proliferation of Schwann sheath cells and degeneration of neurons in the ganglia. The infiltration may be mild and confined to perivascular areas or diffuse; or dense and diffusely scattered in the nerves. The inflammatory lesions are usually confined by the nerve sheath, although in some instances a similar perineural infiltration may be observed. The neoplastic lesions differ from the inflammatory in that the infiltrating lymphoid cells have a neoplastic character, are actively multiplying, and may be so aggressive as to almost entirely replace the nerve elements within the nerve sheath. Such neoplastic areas may readily encroach upon and penetrate the nerve sheath with infiltration of the adjacent tissue. It would be a simple matter to separate cases of fowl paralysis into a group with inflammatory lesions and a group with neoplastic lesions if it were not for those cases in which one type of process seems to merge into the other. Such a separation would, therefore, have to be made on a purely arbitrary basis.

The primary purpose was the study of a group of lymphocytomas and not of fowl paralysis, which meant that it was necessary to establish certain criteria for the cases to be included. Such a plan is based on the premise that lymphocytoma and fowl paralysis are different disease processes. In view of the fact that lymphocytoma may be found in almost any tissue of the body, it did not seem reasonable that nerve tissue would be immune or resistant to such a tumor. The plan developed and followed for this study, therefore, was to include all cases in which any organ or tissue, including nerve, was suspected of being involved with neoplasia. Those cases of fowl paralysis in which gross examination made it reasonably certain that the lesions were confined by the nerve sheath, leaving the visceral organs free of neoplasia, were not included. The plan would thereby exclude many cases of fowl paralysis in which the nerves were infiltrated with neoplastic lymphoid cells, for these cannot be distinguished on gross examination from the cases in which the lesions are inflammatory in character (Plate III, Figures 5 and 6).

Among the 213 cases of lymphocytoma were 83 in which nerves were involved (Table 2). Of this number (83), there were 23 cases in which the nerve lesion or lesions were confined to an area in which the adjacent extra-neural tissue was likewise infiltrated with lymphocytoma. The question arises of whether or not such cases represent an extension of the process from within the nerve to without or the reverse. As judged from this material, it would seem that both would occur. There were 19 cases in which nerve lesions were confined to either the nerve of Remak[3] or the anterior mesenteric plexus and immediate nerve radical, and lymphocytoma was found in the adjacent tissue of the gonad, peritoneum, or adrenal. In the majority of these the pathology suggested that the tumor

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[3] The main trunk nerve of the mesentery arising from both the anterior and posterior mesenteric plexuses of the autonomic nervous system.

invaded the nerve from without, for the nerve was the more lightly infiltrated (Plate III, Figure 2). In 3 cases, lymphocytoma was confined to the soft tissue surrounding nerves in the regions of either the brachial or lumbosacral plexuses and immediate radicals.

An interesting finding in this collection of lymphocytomas was the relatively small number of cases of the nodular type in which nerves were involved (Table 2). A ratio of about 2 to 3 existed between the cases with and without nerve involvement when lymphocytoma was either diffuse or diffuse and nodular in type. This ratio changed to 1 to 9 in nodular lymphocytoma. Actually only two cases of nodular lymphocytoma were observed in which nerves were involved. One of these was an extension of lymphocytoma of the adrenal and ovary into an anterior mesenteric nerve ganglion and might easily have been overlooked. The significance of this finding is obscure. The number of cases is small, and it is possible that the observation may be due to chance.

The explanation of the group of 60 cases with nerve involvement at a site removed from lymphocytoma of other tissue is subject to a difference of opinion. A number of conceptions are possible. They may represent instances of metastasis of the tumor to a nerve from a primary focus situated in a visceral organ. They may have developed in the nerve in response to a hypothetical causative agent of lymphocytoma. They may be lesions of fowl paralysis existing coincidentally with lymphocytoma, assuming that there are separate agents responsible for each disease. Or a single agent may be responsible for both lymphocytoma and fowl paralysis and the response in nerve or other tissue depend upon factors as yet unknown. These questions cannot be answered from the data, and a satisfactory explanation must await settlement of the problem of etiology of the diseases.

No satisfactory explanation has been advanced for the existence of different types of lymphocytoma. Nodular and diffuse lymphocytoma have been recognized and described by Feldman (7) and Mathews and Walkey (19), as well as others; and another manifestation—combined diffuse and nodular lymphocytoma—has appeared in this study. A possible explanation for these different types has developed as a result of this study, based on the theory that the host exerts a variable degree of resistance against growth of the tumor. Thus, diffuse lymphocytoma is a disease in which little resistance is offered on the part of the host, and the nodular form develops when considerable resistance to growth is offered. The diffuse and nodular form results when the resistance is moderate in degree. The data do not provide conclusive evidence for such a theory, but do offer some support. On the basis of such a contention, one would expect that the type of disease in which most resistance was offered by the host would be the least widespread, and this was the finding in the case of nodular lymphocytoma (Table 6). One might also expect that the degree of individual organ involvement would be least in the nodular form, and it was found that 37.9 percent of the affected organs were Grade 1 or 2 in cases of nodular lymphocytoma as compared to 29.4 percent Grade 1 or 2 in cases of diffuse lymphocytoma (Table 8). Although data with respect to organ weights indicated no statistically significant difference between the three forms of lymphocytoma (except in the case of the kidney), the suggestion remains that the relative weights are greater in diffuse lymphocytoma. A larger series of cases in which the organs have comparable grades of involvement should be examined to settle this point. The histology of the different types also lends itself to support of the theory of resistance on the part of the host. A nodular, circumscribed focus of lymphocytoma surrounded by a connective tissue wall of variable thickness suggests an attempt on the part of the host to localize and wall off the tumor from the rest of the body (Plate III, Figure 4). Reactions of this type have been noted in

the later stages of regression of implants of a transplantable lymphoid tumor of the chicken (Olson 22).

The results of the study seem to indicate that lymphocytoma is a systemic disease affecting the widely distributed lymphoid cell system. The histogenesis of lymphocytoma, therefore, does not conform with the commonly accepted theory of histogenesis of neoplasia in which it is believed that tumors arise as the result of a single cell or localized focus of cells assuming a state of neoplasia. In spite of this feature, the invasiveness and apparently purposeless progressive growth of lymphocytoma seem sufficient to characterize the disease as a neoplasm. Lymphoid tissue capable of becoming transformed into the malignant cells of a lymphocytoma probably exists in nearly every part of the body, yet certain organs were more often affected with the disease than others. These organs are not necessarily those rich in lymphoid tissue, for the bone marrow, thymus, and bursa of Fabricius in which such tissue is abundant were not found affected as often as other organs relatively deficient in this respect. It is reasonable to believe that the lymphoid tissue of such organs as the liver, spleen, kidney, and gonad, in which lymphocytoma was more commonly found, is more susceptible to the action of the hypothetical causative factor or factors of lymphocytoma. This susceptibility may be due to some particular functional state of the lymphoid tissue in those organs in which the disease occurs.

Myelocytoma

Pentimalli (25) described two cases of this disease and applied to it the term "myelocytoma." Mathews (17) later gave an excellent description of the gross and microscopic characteristics of 37 spontaneous cases to which he applied the term "leukochloroma," adopted from a similar tumor of man which often has a green color that is lacking in myelocytoma of the chicken. This fact together with the prior application of the term "myelocytoma" would seem to be ample justification for the use of the latter term. Twenty cases of myelocytoma were encountered in this collection of neoplastic disease of the chicken. These cases fit into the descriptions given by Mathews and, therefore, only a cursory resume is necessary.

The average age at necropsy of 8 birds that died was 35.2 weeks, with the oldest 55 weeks and the youngest 16 weeks. The average age of 12 birds that were killed for examination was 32.7 weeks, with a maximum of 56 and a minimum of 5 weeks. The age of birds with myelocytoma was more nearly like that of birds with lymphocytoma than that of birds with leukosis (Tables 3, 11, 13). The sex distribution was 15 females and 5 males, or a ratio of 3 to 1. Two cases of myelocytoma were found to be associated with leukosis and are discussed in the section dealing with leukosis. One case was found to be associated with embryonal nephroma, and one with fowl paralysis.

The liver was involved with the tumor in 16 instances. The amount of infiltration varied considerably but in general was moderate and usually confined to the periportal areas. In two cases there was a rather marked hyperplasia of lymphoid elements in the periportal areas in addition to infiltration with neoplastic myelocytes. Since myeloid metaplasia may occur in the periportal areas of the liver in chickens without myelocytoma, it becomes necessary to establish an arbitrary standard for the diagnosis of myelocytoma in the liver. The standard set in this work was that the myelocytes of a myelocytoma were to be at the same stage of development; that is, there should be no evidence of transitional forms from the lymphoid elements of the periportal areas to mature granulocytes. When such a condition was found, the process was regarded as myeloid metaplasia and not myelocytoma. Myeloid metaplasia may be noted frequently

in the liver of the chicken and was a secondary finding in the livers of two cases of myelocytoma. The livers affected with myelocytoma were usually not so large as those affected with lymphocytoma (Plate IV). The average weight of eight affected livers was 5.65 percent of the body weight, with extremes of 14.6 and 3.2 percent (Table 11). The figure for average size is slightly high, for the value in six of the eight cases was less than 5.65 percent.

TABLE 11.—SUMMARY OF DATA ON TWENTY CASES OF MYELOCYTOMA

Figures in parentheses indicate number in group.

	Age at Necropsy (Weeks)		Weight of Organs Expressed as Percent of Body Weight		
	Died (8)	Killed (12)	Liver (8)	Spleen (8)	Kidney (4)
Maximum	55	56	14.6	.86	.80
Minimum	16	5	3.2	.37	.39
Average	35.2	32.7	5.65	.55	.622

Additional Notes: 2 cases were associated with granuloblastic leukosis.
1 case was associated with embryonal nephroma.
1 case was associated with fowl paralysis.

The spleen was involved in 12 of the 20 cases. The average size was 0.55 percent of the body weight in eight instances. Diffuse infiltration of the pulp with neoplastic myelocytes was the characteristic finding.

In eight instances the kidneys were affected. The degree of involvement varied from a slight intertubular infiltration to almost complete replacement of parenchyma with solid masses of myelocytes. The average weight of four affected kidneys was 0.622 percent of the body weight. This figure is not a fair example, for it represents the findings on only two cases.

Other organs and the number of times they were found affected are as follows: gonad 13, parathyroid 8, thymus 6, lung 5, thyroid 5, adrenal 4, pancreas 3, and heart 2. Histological examination was made of the lung and thymus in only 6 cases. The nerve ganglia of the anterior mesenteric plexus were infiltrated by extension from the adrenal in 4 cases (Plate V, Figure 1). In 12 cases, there were either sheetlike or nodular masses adjacent to the visceral or parietal peritoneum. A common finding was the arrangement of soft white nodular tumor tissue near the ribs, concentrated at the costochondral junctions or on the sternum (Plate IV). In one instance the tumor was spread along the spinal column of the trunk, tending to infiltrate the bodies of the vertebrae, as in two cases described by Mathews. The bones of the skull were affected with myelocytoma in two instances (Plate V, Figures 3 and 4). In one, the process was confined to the region of the nasal sinus; and in the other, the disease affected the dorsal aspect of the cranium and was also found on the ventral aspect of vertebral column in the region of the testis.

A variable number of myelocytes was noted in the lumens of the blood vessels of tissues at the time of microscopic examination. Smears of the blood obtained before death were available for study in only four cases. In several cases imprint preparations of tumor nodules were prepared by staining with May-Grunwald and Giemsa solutions for comparison with the myelocytes found in the blood stream. The myelocytes comprising the tumor were found to be identical with those in the blood stream and were at a nearly comparable stage of development.

Many myelocytes contained round polychromatophilic granules and some spindle-shaped acidophilic granules (Plate V, Figure 2). Mathews (17) stated that bone marrow taken from any part of the skeleton in his series of cases of myelocytoma showed some neoplastic-like hyperplasia. The bone marrow of the femur was examined in 15 of the cases in this study (in 5 cases no marrow was preserved), and in all there were areas considered to be identical with the extramedullary foci of neoplasia. In many of the cases examined, the granuloblastic elements of the marrow were almost entirely converted to a tissue resembling myelocytoma.

An infiltration of the mucosa of the intestine, especially in the duodenum, was apparent upon gross examination of two cases. These consisted of small gray masses representing villi swollen with an infiltration of myelocytes. In three other cases, infiltration of the intestinal mucosa was found upon histological examination.

Data on egg production were available on only three cases of myelocytoma (Table 12). Two of the birds could be considered good producers of eggs and the third was a poor producer. The average production index was 0.610, or slightly higher than that found in cases of lymphocytoma. Egg production ceased, on an average, 21 days preceding necropsy of the three cases.

TABLE 12.—DATA ON EGG PRODUCTION OF CHICKENS WITH MYELOCYTOMA.

Productive life is the interval between first and last eggs laid.

Production index is the factor obtained by dividing the number of eggs laid by the productive life in days.

Case No.	Age at Necropsy (Days)	Productive Life (Days)	Number of Eggs Laid	Production Index	Interval from Last Egg to Necropsy (Days)
T 31	*K 319	133	76	.571	20
T 2426	D 389	105	89	.847	16
T 681	D 308	90	37	.412	28
Average	339	109	67	.610	21

*K indicates that bird was killed for examination; D, that it died.

Fowl Leukosis

The collection of neoplasms of the chicken contains 19 cases of fowl leukosis (Plate X, Figures 5 and 6). Both erythroblastic (17 cases) and granuloblastic (2 cases) forms of the disease were found. Since the general pathology of spontaneous fowl leukosis is well discussed elsewhere, no attempt is made to describe the general pathological findings. The pathology was similar to that of cases previously described (Feldman and Olson 8).

The average age at necropsy of chickens with leukosis was approximately 47 weeks, or slightly older than in cases of lymphocytoma (Table 13). The sex distribution was 17 females and 2 males, or a ratio of 8.5 to 1. The average percentage of body weight for the liver, spleen, and kidney in 12 cases of leukosis is indicated in Table 13. This value is lower than in cases of lymphocytoma for the liver and kidney, and slightly higher for the spleen.

TABLE 13.—SUMMARY OF DATA ON NINETEEN CASES OF FOWL LEUKOSIS

Figures in parentheses indicate number in group.

	Age at Necropsy (Weeks)		Weight of Organs Expressed as Percent of Body Weight		
	Died (10)	Killed (9)	Liver (12)	Spleen (12)	Kidney (8)
Maximum	114	99	9.12	1.87	1.18
Minimum.......	16	24	3.75	.39	.54
Average.....	47.7	47.5	6.71	.99	.76

A fibrosarcoma of the musculature in the region of the scapula was found in one case of erythroblastic leukosis. The tumor measured approximately 3 × 3.5 × 2 cm. and was infiltrative in character. It represents an interesting finding because of the potentiality of some strains of the leukosis agent to induce fibrosarcoma (21). Lymphocytoma of the kidney and proventriculus was associated with one case of erythroblastic leukosis. In one case of leukosis, a slight enlargement of the posterior portion of the nerve of Remak was noted, which proved to be due to an infiltration of erythroblastic cells. This may have been caused by escape of leukotic cells from the blood and their local proliferation in the tissue. Hermorrhage had occurred in six cases. In four of these, capillary hemorrhage was found in either the intestinal mucosa or subcutaneous tissue; and in the other two, hemorrhage came from rupture of the liver and spleen capsule respectively.

Both cases of granuloblastic leukosis were associated with myelocytoma. In one, foci of myelocytoma were found in the liver, kidneys, ovary, bone marrow, thymus, pancreas, and under the parietal peritoneum of the sternum. In the other, the myelocytoma was not so widespread, involving only the liver, kidneys, ovary, and bone marrow. The diagnosis of leukosis in both of these cases may be open to question. The pathology of the marrow may be regarded as the most significant feature in support of the diagnosis of leukosis. Both erythropoiesis and granulopoiesis were stimulated far beyond normal limits and the foci of myelocytoma found upon histological examination were confined to localized areas.

Encroachment of the marrow by infiltration of any tumor tissue will affect the normal function of bone marrow but this does not lead to leukosis as indicated by the findings in cases of lymphocytoma or other cases of myelocytoma, where replacement of myeloid tissue may cause an aplastic anemia or leukopenia. In some instances immature blood cells may enter the circulation because of a mechanical disturbance by the tumor in the marrow.

Fibroma

The diagnosis of fibroma was made on five tumors in the collection. In these cases the type cell of the tumor was a neoplastic fibroblast more mature in character than that observed in fibrosarcoma. A brief description of the five cases follows.

1. T 40. A 4-week-old male chicken was found dead with a growth in the subcutis immediately below the left eye. The tumor mass measured 4 × 2 × 1.5 cm. and weighed 13 grams. There was no evidence of metastasis and the cause of death was not determined.

2. T 251. Swelling of the right eye and excessive lacrimation was noted in a 32-week-old hen. The bird was killed for examination. A tumor mass in the right nasal passage and sinus was found to be responsible for the swelling of the eye. The tumor was irregular in outline, firm, and contained several small cysts. The cysts were lined with columnar epithelium and probably represented portions of the respiratory mucosa pinched off by growth of the fibroma.

3. T 253. A 28-week-old pullet was noted as slightly dull and submitted to the laboratory for examination. Upon necropsy, a large tumor weighing 190 grams was found in the wall of the large intestine about 2.5 cm. from the vent. The tumor encircled the intestine, though the lumen was eccentric in position (Plate VI, Figure 1). The substance of the tumor was very tough and fibrous (Plate VI, Figure 3).

4. T 293. A male, killed for examination at the age of 15 weeks, was found to have a slight swelling of the region over the right nasal sinus. A tumor measuring 20 × 12 × 10 mm. was found in the nasal sinus displacing the structures lateral to it.

5. T 1327. A one-year-old pullet died from cannibalism. In the left ventricular wall of the heart was a firm, gray mass measuring approximately 3 × 2 × 1 cm., which proved upon section to be a fibroma (Plate VI, Figure 2). A Van Gieson's preparation was made of a section of the tumor to eliminate the possibility of the tumor's being of muscular origin. The reaction was characteristic of fibrous tissue. A record of the egg production of this bird was available. It had laid only 32 eggs during a productive life of 98 days, which gives a production index of 0.326. This is lower than the average for the flock. (See section on Lymphocytoma for discussion of the production index.) The last egg was laid 80 days previous to the death of the bird.

It is of interest to note that in two of the five cases, the fibromas were located in the nasal sinus. In one case of fibrosarcoma, also, the tumor was in the nasal sinus. These facts suggest that the nasal sinus is a likely site for the development of fibroblastic tumors, although a survey of the literature on avian tumors does not bear out the suggestion.

Although fibromas are ordinarily considered benign, the tumor was the primary reason for examination in four of the cases and represented the principal pathological finding.

Myxoma

Two cases of myxoma were found in the collection. A short description of each follows.

1. T 81. A 6-month-old Rhode Island Red male was found dead. Its abdomen was filled with a 717-gram tumor attached to the left kidney. The surface of the tumor was smooth, glistening, and yellow-white in color. On cross section the tissue of the tumor was spongy and cystic and much distinctly mucinous fluid could be pressed from the cut surface. Most of the left kidney was destroyed by the tumor. The tumor was composed of a very loose arrangement of small stellate cells with anastomosing processes. No metastatic or implantation nodules of tumor could be found.

2. T 197. A 7-week-old Barred Plymouth Rock male was submitted for examination because of swelling in the region of the left eye. The bird was killed and examined. A yellow-white, irregularly lobulated tumor was found in the orbital cavity, which caused protrusion of the left eye. The histology of the tumor was similar to that of case T 81. No other pathology was found.

The morphology and mucin production of the type cell of these two tumors clearly indicates their embryonal character (Plate VI, Figures 4 and 5). Although myxosarcomas (malignant tumors of the same type cell) have been found in the chicken by different observers (Olson 20), no additional cases were found in the present survey.

Fibrosarcoma

Tumors found in 16 chickens were diagnosed as fibrosarcoma. These cases are listed in Table 14 together with pertinent data.

TABLE 14.—DATA ON SIXTEEN CASES OF FIBROSARCOMA.

Case No.	Age (Weeks)	Sex	Primary Site	Extension or Metastasis
T 18	*K 36	Female	Muscle of left leg	None
T 60	K 52	Female	Muscle of left leg	Gizzard and duodenum
73	D 60	Male	Muscle of left leg	Peritoneum
T 112	K 26	Female	Muscle, near scapula	None
616	K 69	Female	Muscle, right pectoral	Brain
T 44	D 79	Female	Muscle, cervical region	None
T 134	K 32	Female	Peritoneum	Multiple
T 62	K 12	Male	Peritoneum, pelvic cavity	None
T 65	D 52	Female	Peritoneum	Multiple
T 191	D 52	Female	Lungs, bilateral	None
154B	D 51	Female	Kidney	None
T 102	K 20	Female	Liver	Peritoneum
T 818	K 54	Male	Liver	Kidney
T 271	K 28	Female	Subcutis of leg	Kidney
T 214	K 16	Female	Pharyngeal region	None
T 69	K 32	Female	Nasal sinus	Peritoneum, muscle of leg

*K indicates that bird was killed for examination; D, that it died.

Fibrosarcoma was found most often (six cases) as a primary tumor of skeletal muscle. In two cases metastasis to the visceral organs had occurred, and in another case there was metastasis to the brain.

The peritoneum was considered the primary site of the tumor in three cases. In two of these the tumors were multiple, small nodular masses scattered over the serosal surface of the mesentery and some of the visceral organs. In one of these cases the entire intestinal tract and mesentery were drawn into a tight, compact mass by a diffuse covering of the peritoneum with fibrosarcoma. In case T 62, a 530-gram encapsulated tumor found in the pelvic cavity, where it displaced the cloaca and rectum to the right, was considered to have originated from peritoneum although its precise point of origin could not be determined.

Bilateral fibrosarcomas were found in the lungs of one chicken and in no other site. These may represent multicentric points of origin or a spread from one lung to the other.

In the remaining six cases of fibrosarcoma the primary site of the tumor was the kidney, the liver, the subcutis of the leg, the region of the pharnyx, and the nasal sinus.

Although there was some variation in the histology of the different cases of fibrosarcoma, the type cell of the tumors was a neoplastic spindle-shaped fibroblast (Plate VII, Figure 1).

The majority of birds with fibrosarcoma were killed for examination, but there were only two in which the tumor could be regarded as an incidental finding. In other words, the tumor was usually responsible for the disturbance in health that led to necropsy. The age of birds affected with fibrosarcoma ranged from

12 to 79 weeks with an average of 42.0. Thirteen of the birds were females and three were males.

Data on egg production were available for only one bird, case T 44. This bird laid 168 eggs during a production period of 328 days. The production index of 0.512 was only slightly lower than the average (0.534) for the flock from which the bird came. The last egg was laid only 41 days before the bird died.

Osteochondrosarcoma

Only one example of osteochondrosarcoma was found. This developed on the skull, dorsal and posterior to the external canthus of the left eye.

1. Case T 234. The owner had noted a swelling on the head of the hen and submitted it for examination at the age of 5 months. The tumor did not seem to discommode the bird. The mass measured approximately 3 × 2.5 × 2 cm. It was firmly attached to the bone of the skull and on cross section many small yellow bony foci were found scattered throughout the substance of the tumor. The major portion of the tumor was faintly blue-gray in color and had a glassy appearance. Microscopically the tumor was composed principally of immature chondroblasts which had produced much intercellular chondromucin. There were scattered areas in which the chondroblasts assumed a more adult form resembling cartilage cells, and in these areas were deposits of calcareous material indicating the formation of bone (Plate VII, Figure 3). The liver, spleen, and bone marrow of the femur were found to be negative for pathology upon both gross and histological exmaination.

Fibrochondrosarcoma

Only one case of fibrochondrosarcoma was encountered.

1. Case S 2630. This tumor was found in the subcutis of the back, in the pectoral muscle, in muscles of the thigh, and in the tendinous, aponeurotic attachments of muscles to the sacrum and patella of a year-and-a-half-old hen that was killed for examination. The visceral organs and the bone marrow were essentially negative for pathology. The cellular morphology of the tumor was somewhat variable in different areas. In general it was a mixture of immature fibroblast-like cells and immature, neoplastic cartilaginous cells. The latter type of cell was usually predominant. The cartilaginous cells were more or less closely related in a syncitial arrangement. The nuclei were sometimes double and in differentiated areas quite similar to those of adult cartilage cells. The cytoplasm of the cells was a slate-blue color with hematoxylin and eosin stain and as mentioned above the cell borders were sometimes indistinct. The fibroblast-like cells were spindle-shaped with faintly blue staining cytoplasm and had relatively large vesicular nuclei. Transitional forms between the two types of cells were apparent.

The primary site or point of origin of the tumor could not be determined. The tumor of the subcutis manifested itself as areas of thickening of the skin, one of the largest of which measured 35 mm. in diameter. The tumor tissue was gray in color, very firm and fibrous. In the muscles, the tumor had a similar color and appearance and tended to infiltrate and destroy the muscle tissue.

From the data on egg production by this bird a production index of 0.463 was calculated (93 eggs in 201 days of productive life). The last egg was laid 247 days previous to necropsy.

Histiocytic Sarcoma

The term histiocytic sarcoma has been introduced by Jackson (13) to include those tumors which take their origin from the histiocyte. The diagnosis of histiocytic sarcoma requires careful microscopic study of the complex structure of such tumors. Neoplastic histiocytes may assume the form of macrophages, fixed stellate cells, and fibroblasts, in addition to intermediary forms between these cell types. Usually all forms of neoplastic histiocytes may be found to a variable extent in different parts of a typical histiocytic sarcoma.

Three examples of this tumor were found. A brief description of each of these cases follows:

1. T 5. A 7-month-old pullet was killed for examination because of symptoms of general debility. A tumor mass weighing 217 grams was found in the region of the pancreas. Histological section revealed that although it did not actually invade the pancreas this organ was markedly compressed by encircling growth of the tumor. In some areas the tumor was distinctly fibroblastic in character. In other areas the tumor was composed of large, round cells possessing a relatively large vesicular nucleus with a large, distinct nucleolus. In still other areas the arrangement was much less compact and the cells were stellate with anastomosing cell processes. Areas of necrosis were found in the tumor with a polyblastic reaction composed of lymphocytes, plasma cells, and granulocytes on the serous surface of the tumor mass. A marked lymphocytic hyperplasia was observed in the liver, kidney, and proventriculus. Hyperplasia of the myeloid elements of the bone marrow was present in which the development of granulocytes was largely definitive.

2. T 52. A somewhat emaciated hen, one year old, was killed by the owner and submitted for examination. There was an excess of cloudy, yellow peritoneal fluid containing masses of rather dry, yellow debris. The visceral serosa was distinctly thickened and the mesentery was shortened causing the intestinal tract to be contracted into a small, firm mass from which it was impossible to separate individual loops of intestine. The liver was enlarged and contained numerous, variable-sized foci of white tissue the largest of which measured 1 cm. in diameter. The centers of these foci were depressed giving them a crateriform appearance. Many of the masses were confluent and others had a sharp, discrete border. The ovary appeared normal and non-functioning yet on section a rather large mass of tumor was found replacing the parenchyma. The tumor covering the serosa and in the liver and ovary was variable in its histological aspect and resembled that found in the case previously described.

3. T 280. This case was a 7-month-old pullet which was killed for examination. A moderate swelling was noted over the left pectoral region. The swelling was found due to a tumor mass in the subcutis overlying the left breast muscle and extending the length of the sternum. The tumor tissue was gray-yellow in color and enclosed cavities some of which were filled with dark brown fluid, while others contained brown or red, gelatinous, fibrinous material. The tumor was intimately associated with the underlying muscle. Both lungs were quite firm and almost completely infiltrated with gray-yellow tissue. The tumor in the region of the breast was composed of a mixture of fibroblastic and large macrophage-like cells (Plate VII, Figure 2). Debris of engulfed cells was evident in the cytoplasm of the large macrophages. In some areas the cytoplasm of the fibroblast-like cells had become fused to form a relatively solid mass of tissue. The histology of the tumor in the lungs was similar to that in the breast region. An incidental finding in this case was a small benign hemangioma occurring as a small nodule in the liver.

Judging from experience with these cases, considerable study is required to make a differential diagnosis between histiocytic sarcoma and fibrosarcoma; yet essential differences occur which indicate that these tumors may be regarded as separate and distinct forms of neoplasia.

Neurogenic Sarcoma

Five neoplasms among the collection of chicken tumors were classified as neurogenic sarcoma. One of these (Case 447) has been previously described (Olson 23) and the others are new to the literature. The salient features of the five cases are as follows.

1. Case 447. A pullet was killed for examination at the age of 23 weeks after having shown symptoms resembling those of fowl paralysis for about a month. A firm, encapsulated mass was found attached to the elements of the right brachial nerve plexus. Some of the tumor was growing in the vertebral canal and compressed the spinal cord. The greater mass of the tumor extended toward the base of the heart and the thyroid gland, being connected with the part in the vertebral

canal by a slender stalk. Histologically the tumor was composed of spindle-shaped neoplastic fibroblasts. The visceral organs and other parts of the nervous system were normal.

2. T 312. A 14-week-old female chick, weak and pale from coccidiosis, was killed for examination. No symptons of paralysis were noted. At the apex of the left lung was a smooth, white nodular mass about which the adjacent lung tissue was molded. Upon dissection the nodule was found to arise from the first thoracic dorsal root ganglion on the left side (Plate I, Figure 1). The tumor extended outward from its origin and infiltrated the adjacent musculature to some extent. It had to be separated from the periosteum of the first rib by cutting. The lung was not inflilitrated by the tumor. The entire mass was irregular and measured approximately $3 \times 2.5 \times 2$ cm. The first thoracic nerve and the small branch from the ganglion to the brachial nerve plexus were not involved. The tumor consisted of fairly well differentiated fibroblastic cells which were arranged in bands and had a tendency to assume whorl-like arrangements. The brain and other portions of the nervous system were examined histologically and found to be normal.

3. T 97. A 29-week-old pullet was killed for examination. The bird was in poor flesh and somewhat inactive. An irregular mass of firm, white, glistening tumor tissue was found in the subcutis of the coccygeal region to the left of the mid line. The mass measured approximately $4.5 \times 3.5 \times 2.5$ cm. The tumor infiltrated the adjacent soft tissue to a slight extent. A stalk of tumor, 2.5 mm. in diameter, passed through an opening in the underlying bone and connected with a large mass of similar tissue spread irregularly in the left sublumbar and subsacral region. The tumor enveloped two posterior dorsal root ganglia of the left lumbosacral nerve plexus. The left psoas muscles were infiltrated by the tumor which also partially encircled the left kidney without invasion. A portion of the tumor extended between the left kidney and vertebral column and formed a large mass medial and caudal to the posterior pole of the left kidney. The histological appearance of the tumor was somewhat variable in different locations. In some areas there was a dense, compact arrangement of plump, spindle-shaped cells with oval nuclei. In other areas the cells were less numerous and arranged in strands with anastomosing processes. In the less dense areas there was considerable amorphous intercellular material and clear, fissurelike spaces. The cells also tended to form whorl-like structures in the less dense portions. A section cut through one of the dorsal root ganglia of the sacral region showed the complete replacement of the fibrous capsule by tumor. Focal accumulations of lymphocytes were found in the dorsal root ganglia of the brachial plexuses and in one of the ganglia of the lumbosacral plexus. These lesions were similar to those seen in fowl paralysis. The peripheral nerves and the nerve ganglia of the anterior mesenteric plexus were normal. The visceral organs were essentially negative for pathology.

4. T 288. A 24-week-old pullet was found dead. Previous to death it had been lame on the left leg. The dorsal root ganglia and radicals to the left lumbosacral plexus were embedded in an irregular mass of dense fibrous tumor tissue (Plate I, Figure 3). The tumor was intimately associated with the periosteum of the vertebrae. On side view cylindrical projections of tumor could be seen to coincide with the location of radicals from the lumbosacral plexus. The tumor extended from the left nerve plexus into the left ischiadic nerve. It was constricted in its passage through the ischiadic foramen and became larger again in the region of the thigh. The anterior portion of the right lumbosacral nerve plexus was surrounded by a similar neoplastic tissue which also followed the path of the nerves through the obturator foramen and into the region of the thigh, where it formed a mass about 5 cm. long and 1.5 cm. in diameter. Both kidneys, both lungs, the ovary, and bone marrow were affected with lymphocytoma. The tumor involving the nerves was fibroblastic in character (Plate I, Figure 4). The cells were arranged in irregular strands and tended to form whorls. In some parts of the tumor were found peculiar formations resembling imperfectly formed nerve endings. In a few instances nerve trunks were included in the section of the tumor and the nerve tissue itself appeared to be normal although the capsule was replaced by tumor. The dorsal root ganglia of the brachial plexus and ganglia of the anterior mesenteric plexus were normal.

5. Case 425. The finding of a tumor in this case was incidental to the principal reason for examination. The bird was a 78-week-old hen and was killed after being tested for susceptibility to a respiratory disease. The anastomosing

nerve branch between the spinal cord and sympathetic ganglion which arises at the level of the fifth thoracic vertebra was distinctly enlarged at a point anterior to the vertebral articulation of the fifth rib. The enlarged nerve joined an irregular firm mass situated in the region of the anterior mesenteric and coeliac nerve plexuses. Nerve radicals extending from the tumor mass were normal. The posterior portion of the left ischiadic nerve was enlarged to a diameter of 7 mm. in the femoral region. The enlargement extended for a distance of 3.5 cm. along the course of the nerve. The histology of the enlargements in both locations was similar and consisted of a mass of proliferating fibroblastic cells tending to form whorls and fissures (Plate I, Figure 2). Except for a cystic thyroid gland no other pathology was found.

A type of connective tissue tumor situated either in or about nerves was a common characteristic of the neurogenic sarcomas. In two cases the tumor was single and affected dorsal root ganglia in the brachial region. In one case the tumor was found in two widely separated nerve trunks. In the remaining two cases the tumors were not localized but rather tended to be widespread and to infiltrate the adjacent tissues as well as the nerves which they surrounded. The association of one case with lymphocytoma and of another case with lesions of fowl paralysis has been regarded as merely incidental and without significance. The fibroblastic elements of the tumors appear to be of low malignancy and in most of the cases have a distinct tendency to form a whorl-like arrangement. Jackson (13) has described a case of multiple neurofibromatosis in a chicken. The histological appearance of the neurofibromas of Jackson's case is similar to that observed in most of the cases of this series. The pathogenesis of the tumors classified as neurogenic sarcoma is obscure. Most if not all may have had their origin from the fibrous sheath covering the nerves. The origin of the neoplasia could not be ascertained in Cases T 97 and T 288, in which the tumor was widespread and involved several nerves in a localized area along with adjacent tissue. Although these two cases differ in this respect from others of the group their histology was similar.

Selection of a term to be applied to these tumors was difficult. Neurogenic sarcomas encountered in human pathology often show a palisading of nuclei which was absent from these cases. The tendency for the tumor cells to form whorls was similar to that noted in multiple neurofibromatosis, although the localization and, in two cases, invasiveness of adjacent tissue are features not noted in multiple neurofibromatosis. For the present it seems logical to classify the tumors as neurogenic sarcoma with the hope that future study of a larger group of similar cases will clarify their identity.

Epithelioblastoma

Although this section is headed epithelioblastoma, two types of neoplasia falling under this classification are discussed separately. These are hepatoma and cholangioma.

Epithelioblastoma was found in 24 cases. The tumor was believed to have originated from the ovary in 8 cases, from the liver in 7, from the pancreas in 5, and from the gizzard, esophagus, skin, and thyroid in the remaining 4 cases. The salient data on 17 of the cases are set forth in Table 15.

The neoplasms originating in the ovary were with one exception of an undifferentiated type. One adenocarcinoma was found. In four instances the tumors were represented by small pedunculated masses attached to the ovary. These are listed in Table 15 as solid adenomas. Although they did not show the acinar arrangement typical of adenomas, they seemed to be benign tumors of undifferentiated epithelial cells (Plate IX, Figure 3). The remainder affected the entire organ. In one case the ovarian mass weighed 177 grams. Five of the tumors were confined to the ovary and the other three had spread by extension

to the peritoneal surfaces (Plate VIII, Figure 1). In one case there were metastases to the lung and in another there were metastases to the heart and parathyroid.

Three of the tumors believed to have originated in the pancreas were composed of undifferentiated epithelial cells (Plate VIII, Figure 4), and two of these had spread by extension to the serosa of the viscera. One adenocarcinoma of the pancreas was found which had extended to the peritoneum, ovary, and adrenals (Plate VIII, Figure 3). A small adenoma was found in the pancreas of a chicken which also had a large fibrosarcoma of the pelvic cavity.

A papillary cystadenoma was found on the lining of the posterior portion of the gizzard and consisted of a cauliflower-like protuberance measuring 17 mm. in diameter.

Table 15. Data on Seventeen Cases of Epithelioblastoma.

Case No.	Age (Weeks)	Sex	Types	Organ Primarily Affected	Extension to other Organs
T 16	*D 36	Female	Carcinoma	Ovary	Peritoneum, heart, parathyroid
T 58	K 104	Female	Carcinoma	Ovary	Peritoneum, lungs
644	D 24	Female	Carcinoma	Ovary	Peritoneum
T 74	D 228	Female	Adenoma**	Ovary	—
T 202	K 28	Female	Adenoma**	Ovary	—
T 236	K 28	Female	Adenoma**	Ovary	—
T 294	K 32	Female	Adenoma**	Ovary	
T 116	D 27	Female	Adenocarcinoma	Ovary	-
T 29	K 104	Female	Carcinoma	Pancreas	Peritoneum
T 63	K 52	Female	Carcinoma	Pancreas	Peritoneum, lungs, ovary
T 123	K 31	Female	Adenoma**	Pancreas	
T 62	K 12	Male	Adenoma	Pancreas	—
758	K 258	Female	Adenocarcinoma	Pancreas	Peritoneum, ovary, adrenals
T 130	K 87	Female	Papillary cystadenoma	Gizzard	-
T 148	K 44	Female	Multiple papillomatosis	Esophagus	—
T 260	K 23	Female	Feather matrix adenoma	Skin	-
T 101	K 24	Female	Foetal adenoma	Thyroid	—

*D indicates that bird died; K, that it was killed for examination.

**These adenomas were composed of solid masses of cells without acinar arrangement. They are tentatively called adenoma to indicate their benign character.

Legend for Plate I

Figure 1. T 312. Neurogenic Sarcoma. Ventral view of spinal cord and nerves. Note the large, fairly well encapsulated tumor mass apparently arising from the dorsal root ganglion of the first thoracic spinal nerve.

Figure 2. Case 425. Neurogenic Sarcoma. The tumor was located in the region of the anterior mesenteric and coeliac nerve plexuses. Note the whorl-like arrangement of cells and also the irregular fissures. Magnification × 100.

Figure 3. T 288. Neurogenic Sarcoma. Dorsal aspect of dissected specimen of spinal column exposing the spinal cord. The tumor is evident as the mass surrounding both the left lumbosacral nerve plexus and the left ischiadic nerve and the anterior portion of the right lumbosacral nerve plexus. See Figure 4 for histology of the tumor.

Figure 4. T 288. Neurogenic Sarcoma. The sheath of the nerve cut in cross section is involved with the surrounding neoplasm. The nerve itself appears normal. Magnification × 60.

Figure 5. T 307. Teratoma of the testis. A small projection of normal testicular tissue extends from the lower aspect of the tumor mass. The tumor weighed 606 grams and was composed of connective tissue and epithelial elements.

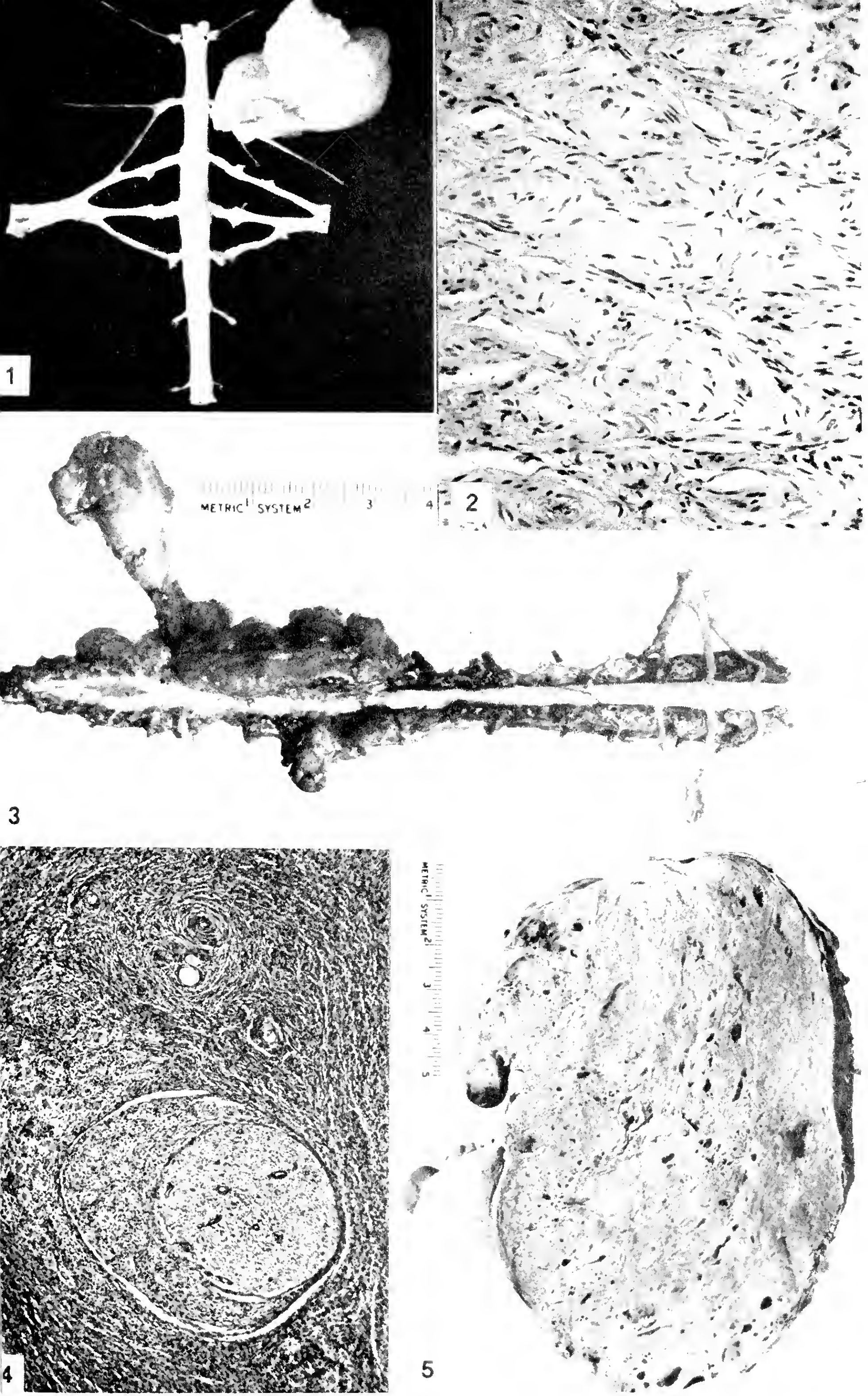


PLATE I

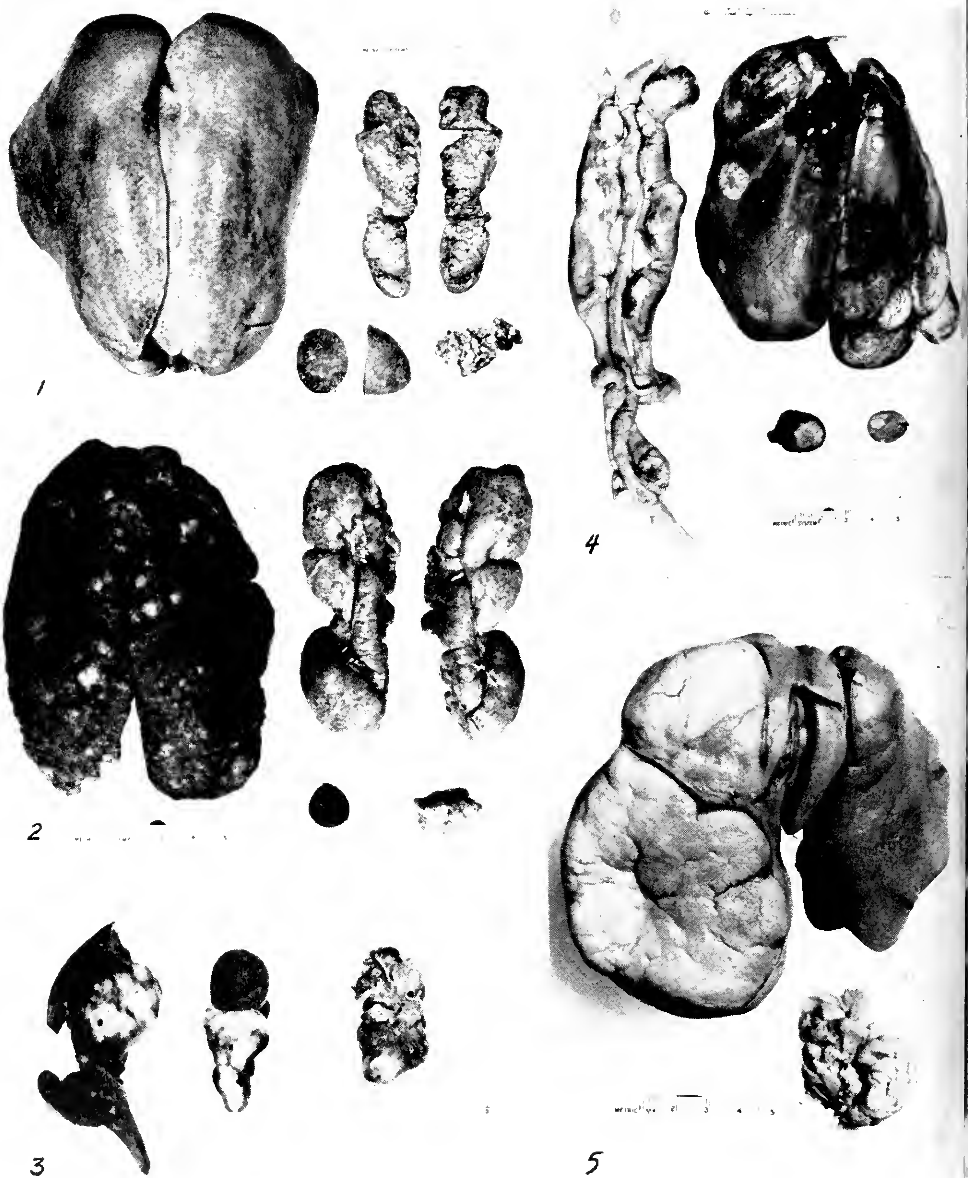


PLATE II

Figure 1. Case 1865. Diffuse Lymphocytoma. Liver, both kidneys, lateral and cross section view of spleen, and ovary. The appearance of kidneys and ovary was normal, but microscopically they were affected with lymphocytoma. The liver and spleen were much enlarged and diffusely infiltrated with lymphocytoma. A photomicrograph of this liver is shown in Figure 1, Plate III.

Figure 2. Case 1846. Nodular Lymphocytoma. Liver, kidneys, spleen, and ovary. The kidneys seemed to be affected with the diffuse form of disease, and the liver with the combined diffuse and nodular form. Histologically the liver, kidneys, and ovary were affected with nodular lymphocytoma. The spleen, shown in cross section, was normal.

Figure 3. Case 299. Diffuse Lymphocytoma. Liver, cross section through gall bladder fossa; spleen with mesentery, cross section; and ovary, with adrenals, cut in cross section to show infiltration of the adrenals. This case illustrates the localization of the neoplasia sometimes observed in the diffuse form of lymphocytoma.

Figure 4. Case 1871. Nodular Lymphocytoma. Lower intestinal tract, including terminal intestine and both cecums, liver, and cross sections of the kidney and spleen. The nodular character of the neoplasm is quite evident in these organs.

Figure 5. T 80. Nodular Lymphocytoma. Liver and ovary. The almost complete destruction of one lobe of the liver was a rather unusual feature of this case. The ovary was only moderately enlarged by the neoplasm.

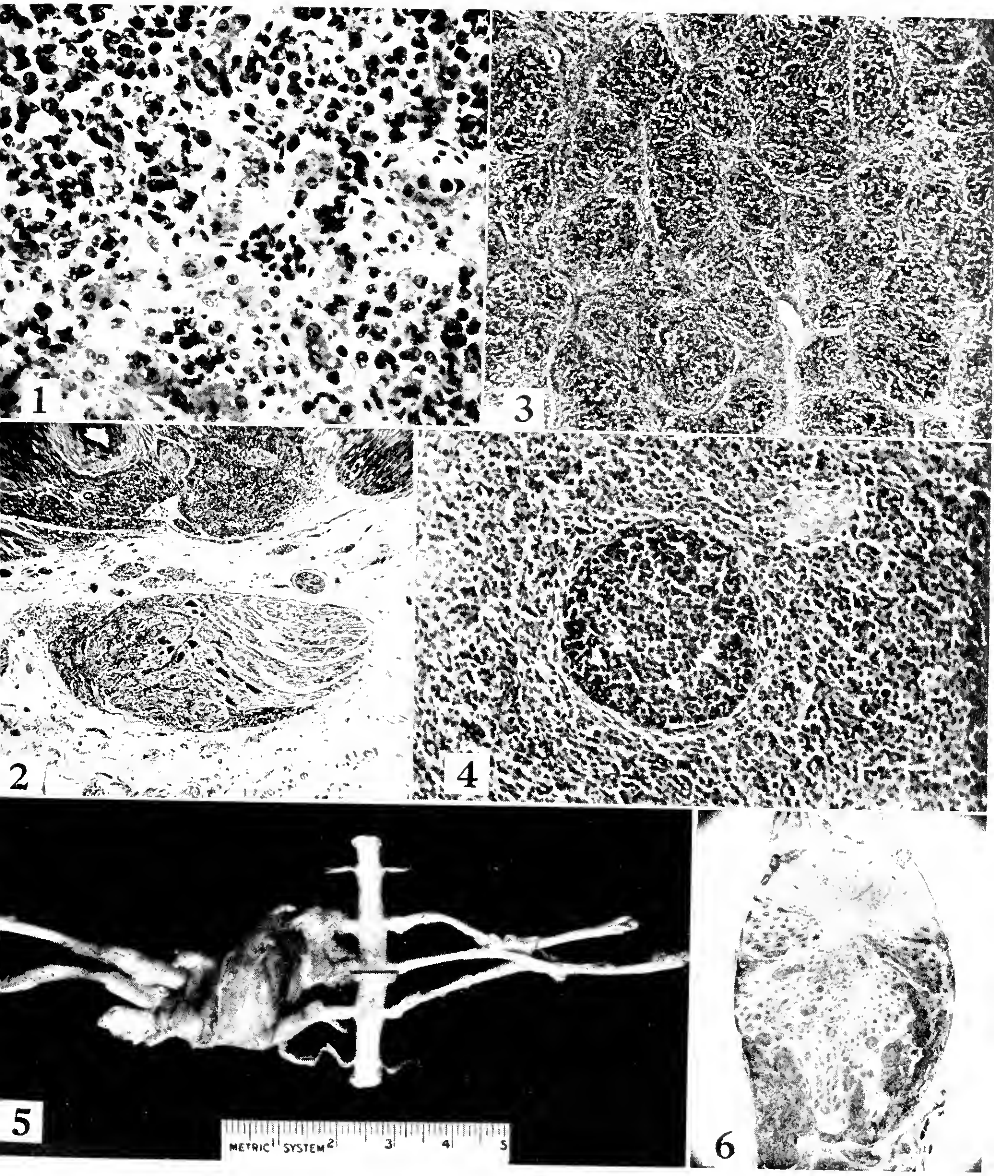


PLATE III

gure 1. Case 1865. Liver with diffuse lymphocytoma. Only a few compressed islands of liver cells remain. The se extravascular growth of the tumor is apparent. Magnification × 300.

gure 2. T 120. Nerve ganglion of anterior mesenteric plexus being infiltrated with lymphocytoma. Penetration of capsule is evident. Both the ovary and adrenals adjacent to the ganglion were affected with diffuse lymphocytoma. Magation × 35.

gure 3. T 118. Ovary affected with nodular lymphocytoma. No ovarian tissue can be seen in the illustration, but only l nests of lymphoid tumor cells surrounded by connective tissue. Magnification × 45.

gure 4. T 178. Spleen showing a single well-encapsulated focus of neoplastic lymphoid cells. The liver, kidneys, peritoneum of this bird were also affected with lymphocytoma. Magnification × 180.

gure 5. Case 1152. Spinal cord and both brachial plexuses of a bird which had paralysis of the right wing. For twelve previous to necropsy the bird was unable to stand and sat on its hocks, with symptoms of a transverse myelilis. The right oral muscles were markedly atrophic. The bird was nearly dead when killed for necropsy. Macroscopic and microc lesions were confined to the right brachial nerve plexus and radicals which were affecled by the swelling illustrated well-encapsulated mass was composed of neoplastic lymphoid cells indistinguishable from those of lymphocytoma. This was not included in the group of lymphocytomas since it failed to meet the criterion of involving tissue other than nerve; serves as an excellent example of what may be regarded as lymphocytoma originating in nerve tissue.

gure 6. Case 1152. Cross section of spinal cord from region indicated by inked line in Figure 5. Much of the cord been destroyed by infiltration with neoplastic lymphoid cells. The invasion proceeds about the vessels and along the l and ventral nerve paths. The marked destruction of nerve tissue no doubt explains the symptoms of transverse myelitis. nification × 6.

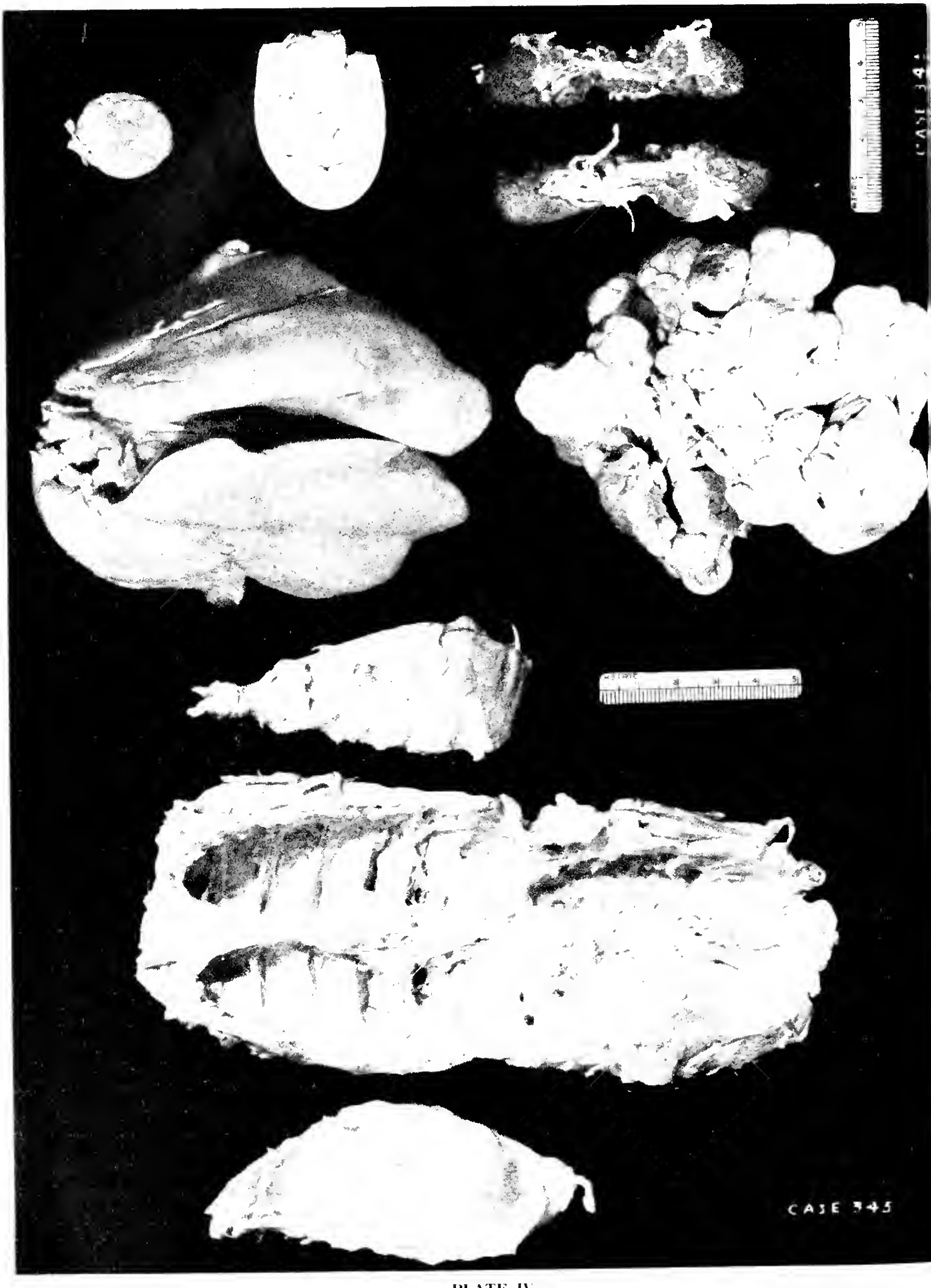
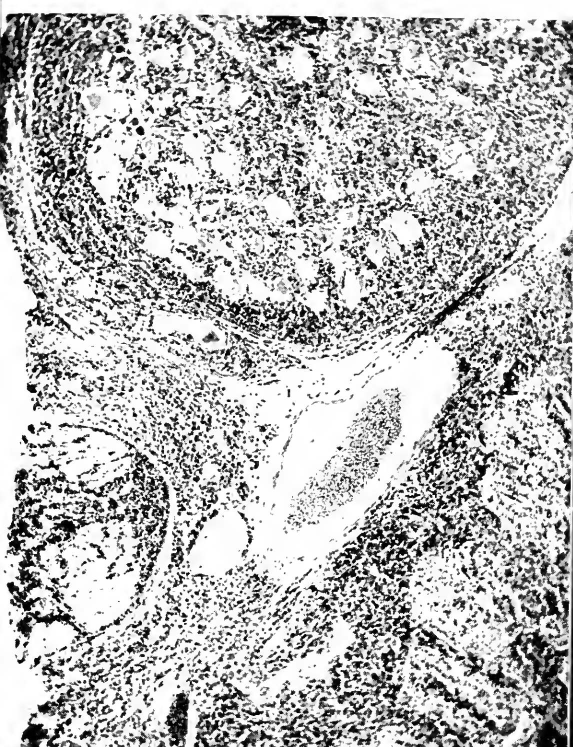
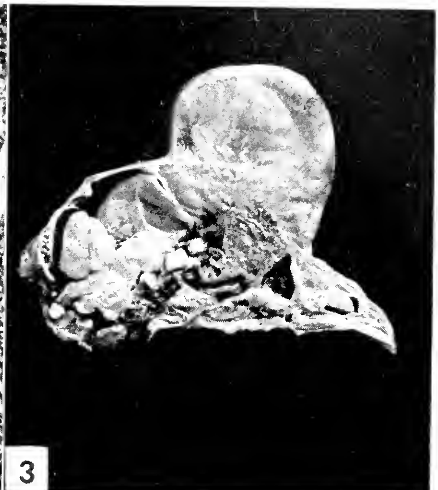


PLATE IV

Case 345. Myelocytoma. Liver slightly enlarged; ovary, markedly enlarged; enlarged spleen, cross section; flexure duodenum and pancreas covered with tumor; and kidneys, normal size, yet microscopically affected with tumor. Body tru ventral view of spinal column and adjacent portion of trunk. Part of the ribs have been cut out and laid back to show cumulations of tumor tissue under the serous lining.





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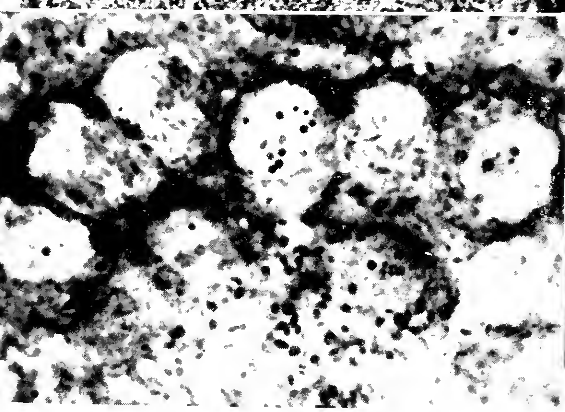

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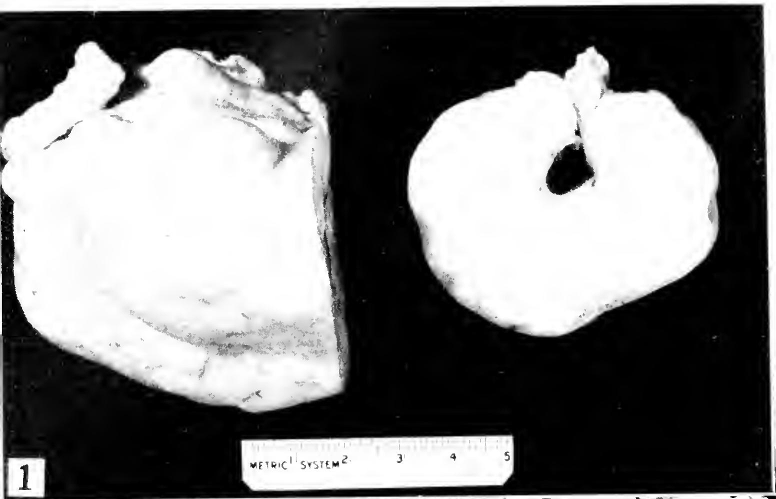
PLATE V

'igure 1. T 161. Myelocytoma. Anterior mesenteric nerve ganglion which is infiltrated with neoplastic myelocytes. : ovary and adjacent tissues of the region were likewise affected. The individual neurons can still be distinguished in ganglion. Magnification × 75.

'igure 2. Myelocytoma. Imprint of tumor stained with May-Grunwald and Giemsa stain. Note both round and spindle-ped granules in the myelocytes. The dark round granules were basophilic and the pale round and spindle-shaped granules 'e acidophilic. Magnification × 1500.

'igures 3 and 4. T 209. Myelocytoma. An unusual case in which the tumor was confined to the skull and periosteum 'ertebral column in the region of the testes. It involved the bone and caused some pressure on the brain (see sagittal 'ion, upper illustration), yet did not perforate the meninges.



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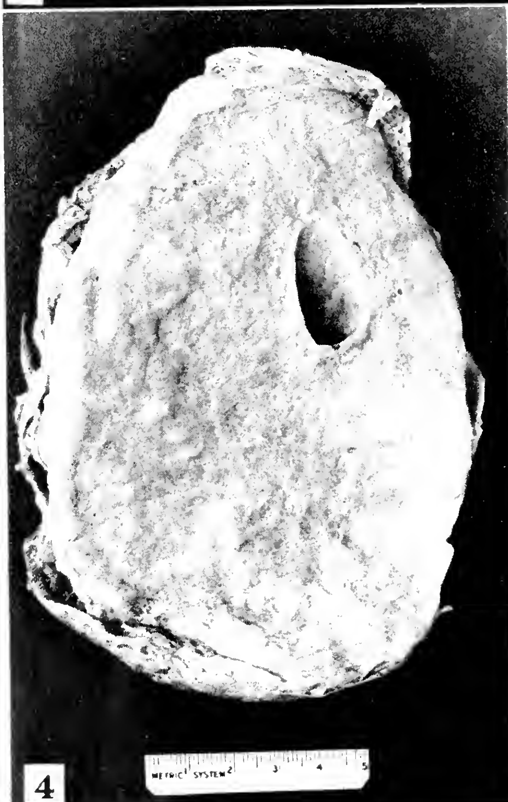

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PLATE VI

Figure 1. T 253. Fibroma encircling intestine. Figure 3 is a photomicrograph of this tumor.
Figure 2. T 1327. Fibroma in ventricular wall of heart.
Figure 3. T 253. Fibroma. Figure 1 illustrates the macroscopic appearance of this tumor. Magnification × 160.
Figure 4. U 2408. Myxoma. This tumor was found in the abdominal cavity, attached to the kidney, weight 1040 gran
This case was encountered after the material for the survey had been collected; hence it is not discussed in the text.
Figure 5. T 197. Myxoma. Note the very loose matrix in which lie stellate cells. Magnification × 270.

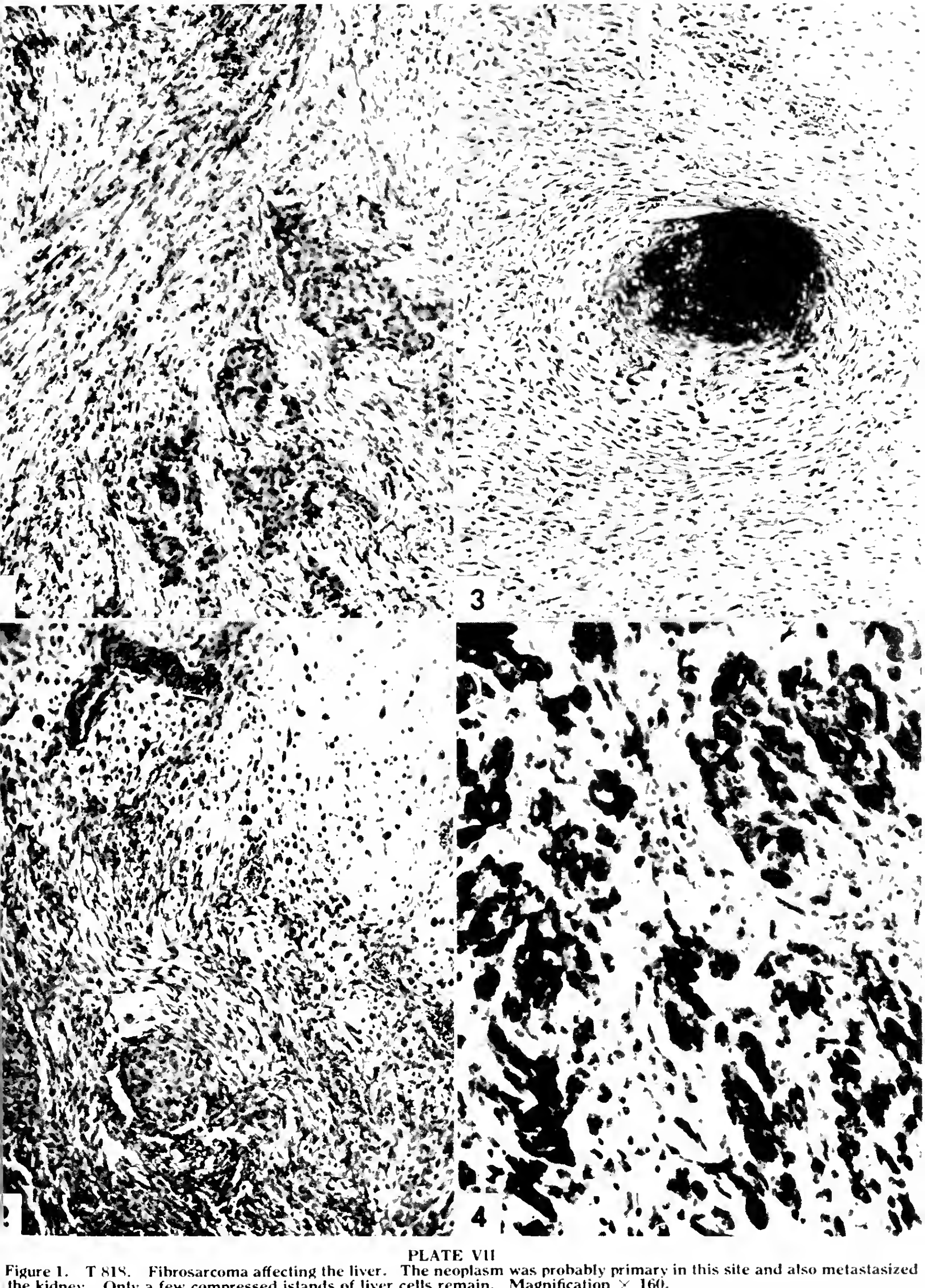


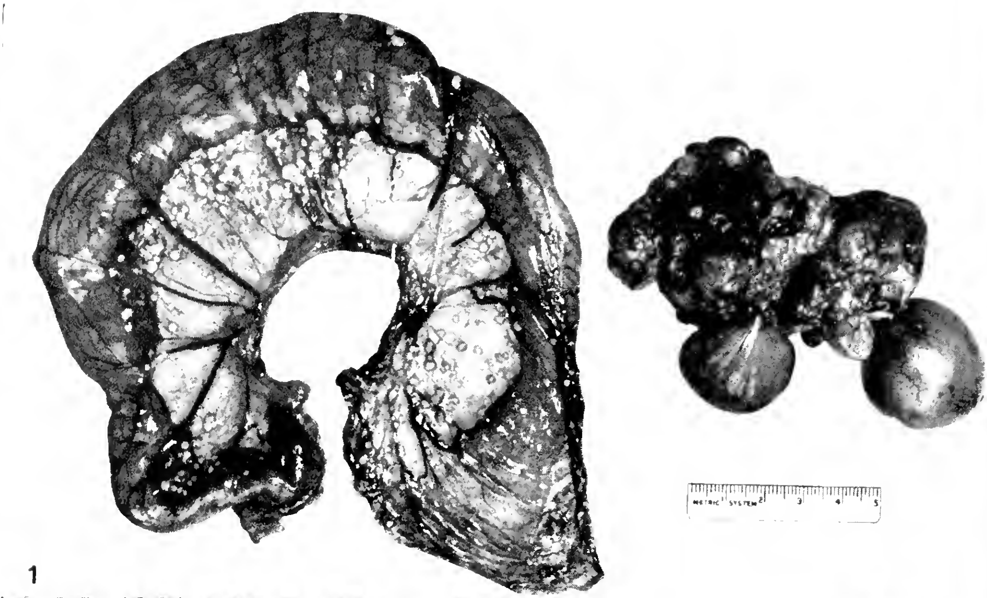
PLATE VII

Figure 1. T 818. Fibrosarcoma affecting the liver. The neoplasm was probably primary in this site and also metastasized the kidney. Only a few compressed islands of liver cells remain. Magnification × 160.

Figure 2. T 280. Histiocytic Sarcoma. The varied character of the tumor is portrayed, showing transitions from sheet-e masses of cells to spindle-shaped cells and finally a very loose arrangement of tissue in which are only a few round tumor lls. Magnification × 100.

Figure 3. T 234. Osteochondrosarcoma. The tumor cells with considerable intercellular collagenlike material surround area of bonelike material developing in a matrix which resembles cartilage. Magnification × 100.

Figure 4. T 101. Melanoma. The majority of tumor cells are heavily laden with melanin. Magnification × 500.



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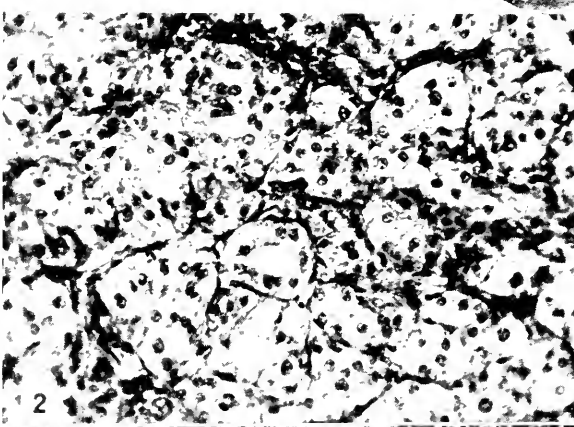

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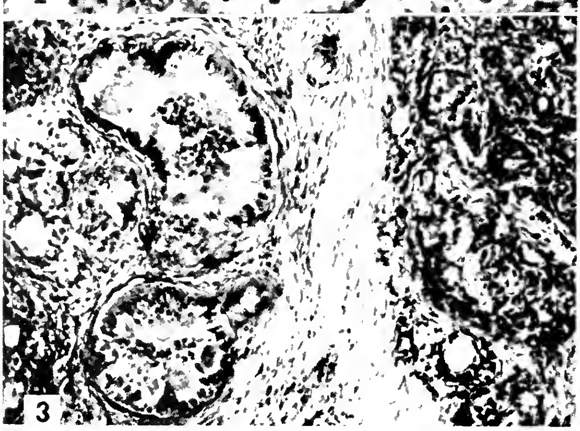

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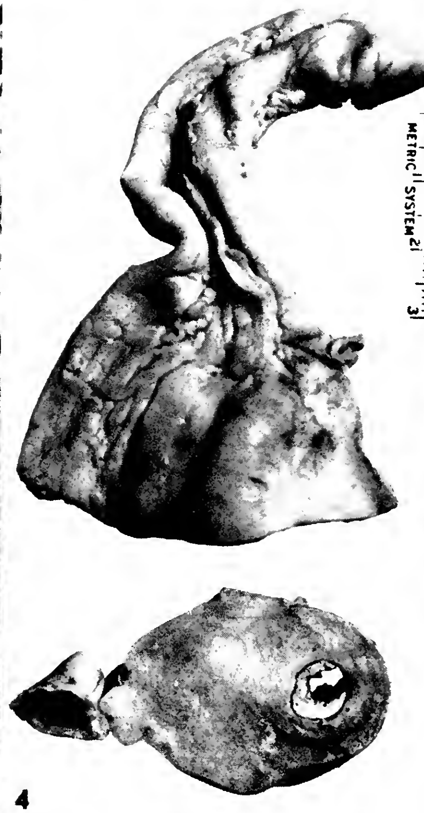

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PLATE VIII

Figure 1. S 601. Adenocarcinoma of the ovary. This case, not included in the discussion, illustrates involvement of the ovary with an adenocarcinoma and multiple implants on the serosa of the oviduct and mesosalpinx.

Figure 2. T 101. Foetal adenoma of the thyroid. Small acini of epithelial cells with no colloid in their lumens characterize this tumor. Magnification × 260.

Figure 3. Case 758. Adenocarcinoma of the pancreas. The section was prepared from a mesenteric implant of the tumor and shows both small and large acini. The latter are filled with cellular debris and pink staining material, probably a secretory product of the lining cells. Magnification × 140.

Figure 4. T 123. Adenoma of the pancreas. Lateral and cross section views of tumor and adjacent duodenum.

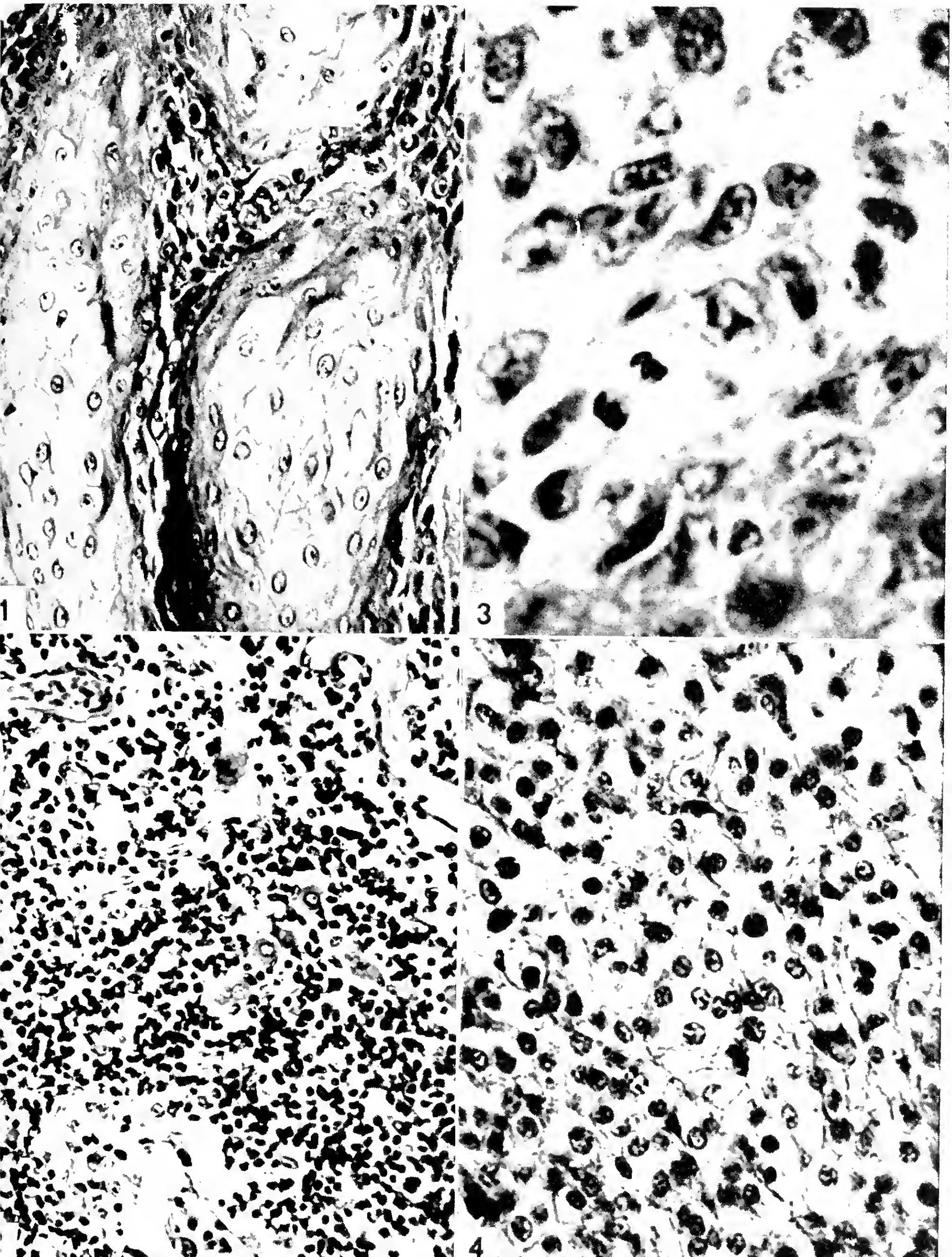

PLATE IX

'igure 1. T 148. Multiple papilloma of the esophagus. The small tufts of epithelial cells are cut in cross sections and ow a tendency to form epithelial "pearllike" structures. Magnification × 350.
'igure 2. T 306. Thymoma. Numerous thymocytes and epithelial cells are shown embedded in an irregular framework reticulum tissue. Magnification × 400.
'igure 3. T 236. Undifferentiated adenoma of the ovary. Although the tumor cells show no tendency to differentiate o any recognizable structure, the neoplasm was confined to the ovary and, therefore, was benign. A single mitotic figure may noted. Magnification × 1500.
'igure 4. T 157. Mesothelioma. Note the sheetlike arrangement of cells and compression which causes polygonal shape cell outline. Magnification × 600.

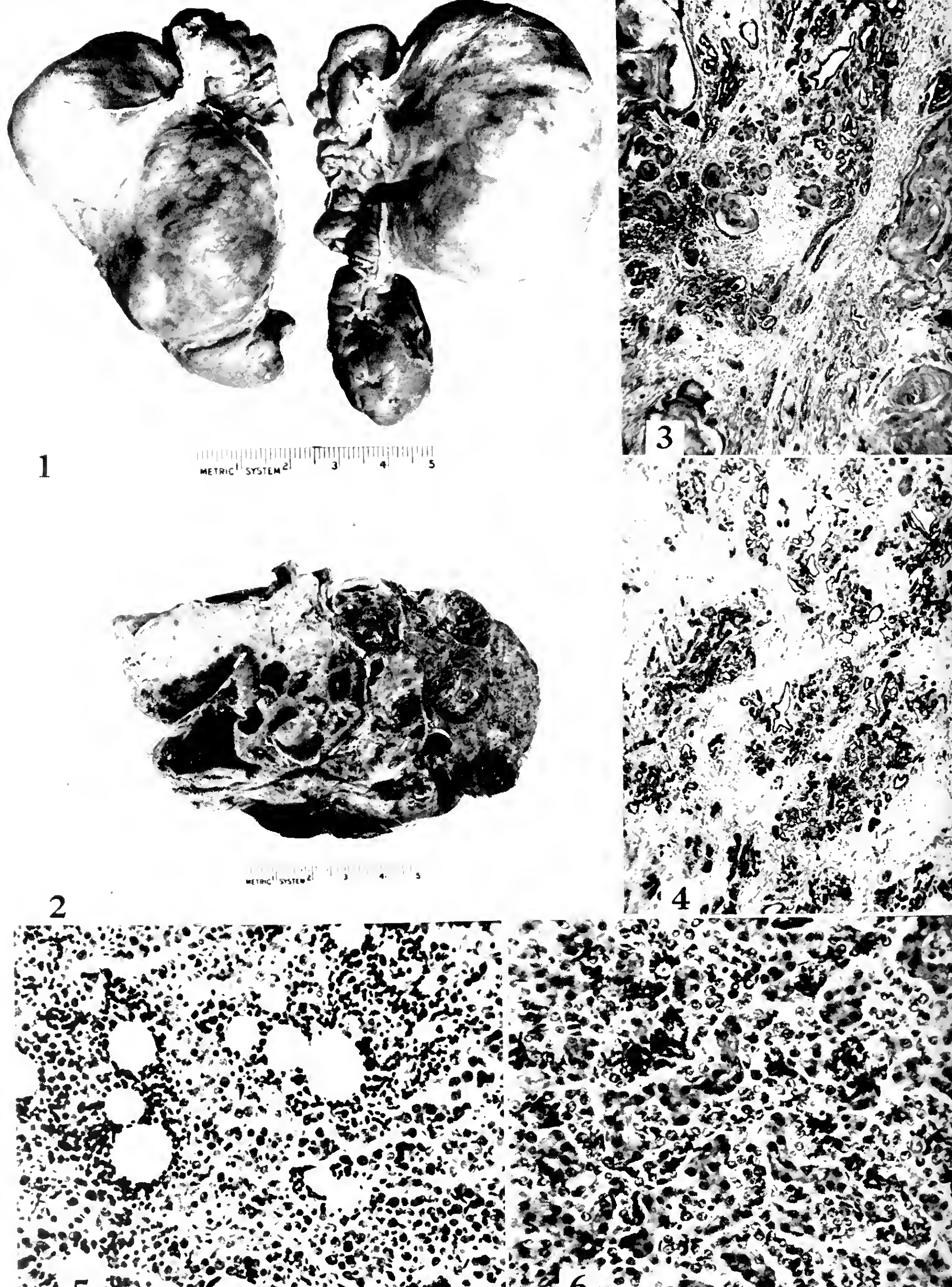

PLATE X

Figure 1. T 69. Bilateral Embryonal Nephroma. Lateral view of tumors arising from the kidneys. Hypertrophy of th unaffected kidney tissue is evident.

Figure 2. T 273. Embryonal Nephroma. The tumor mass of the kidney is cut in cross section to show the polycysti and variable character of the neoplasm.

Figure 3 and 4. T 69. Embryonal Nephroma. Sections prepared from different areas of the neoplasm illustrated i Figure 1. In Figure 3 many "pearls" of keratinizing epithelium are evident. Figure 4 shows a mixture of connective an glandular tissue. Magnification × 30.

Figure 5. T 131. Bone marrow of the femur in fowl leukosis. Note the distended sinusoids filled with immature ery throblastic cells. Only a small amount of extravascular tissue surrounds the isolated clear spaces formerly occupied by fa cells. Magnification × 270.

Figure 6. Case 6122. Liver in fowl leukosis. The sinusoids are filled with immature blood cells which tend to stagnal and cause compression of the cords of liver cells. Magnification × 270.

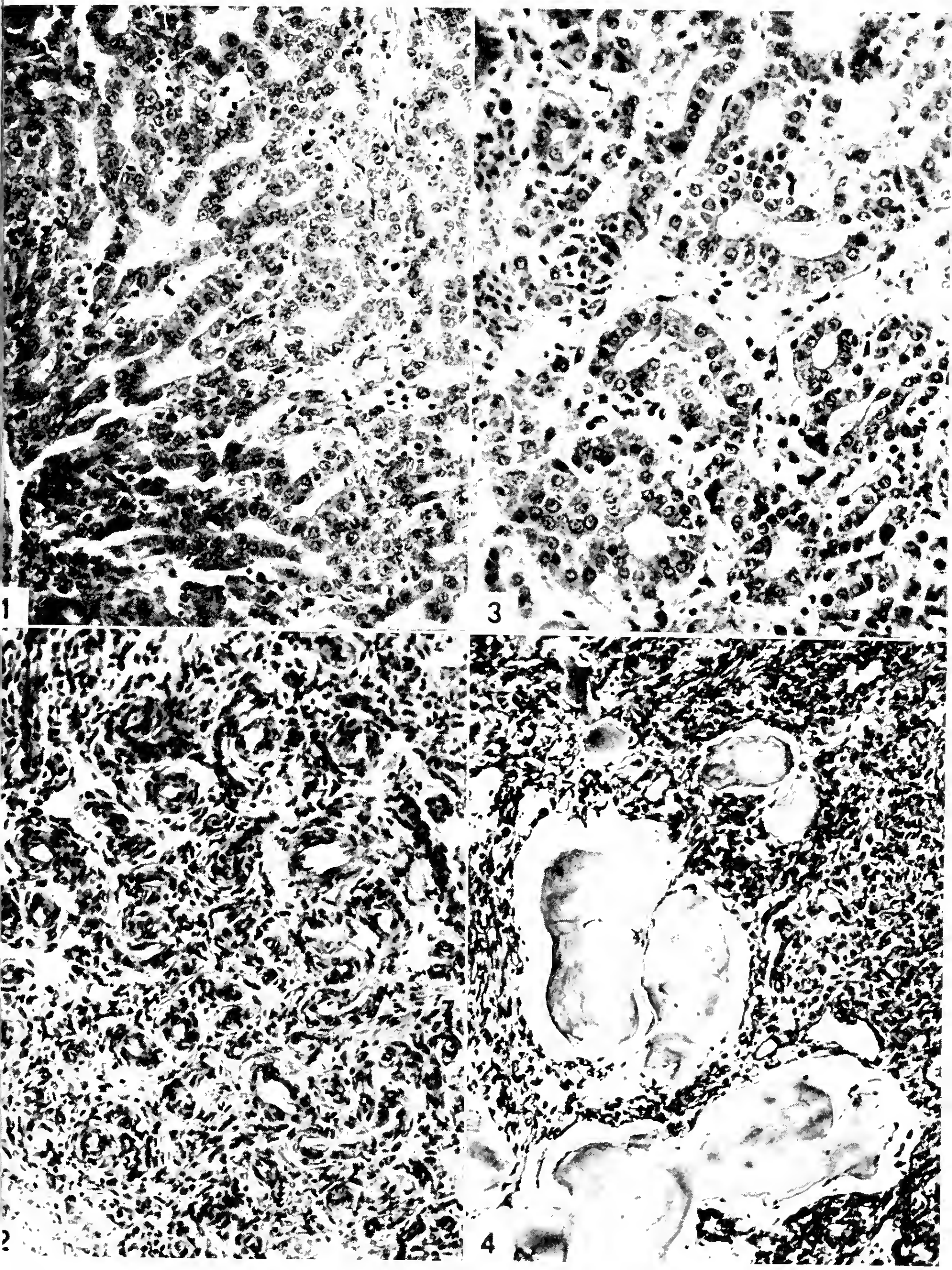

PLATE XI

'igure 1. Case 438. Hepatoma. Note the tendency of the tumor cells, which are very similar to normal liver cells, to m rows leaving sinusoid-like spaces. Magnification × 300.

'igure 2. T 280. Hemangioma of the liver. The distinctive arrangement of the tumor cells in the form of small thick-lled blood vessels is illustrated. Magnification × 200.

'igure 3. T 286. Cholangioma. The neoplasm found in the liver was composed of irregular acini of bile duct epithelium. ıgnification × 300.

'igure 4. T 264. Lymphangioma. This unusual tumor was attached to the ovary. Large spaces filled with pink amor-ous material (lymph) were lined with flattened endothelial cells. Smaller empty vessels may be noted. Masses of endo-lial cells without definite arrangement compose the rest of the neoplasm. Magnification × 120.

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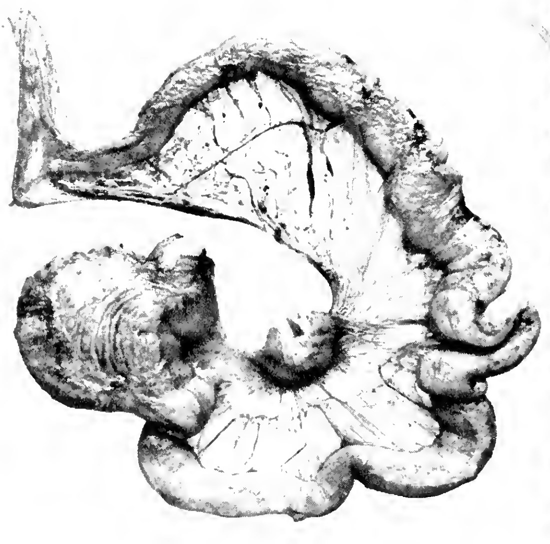

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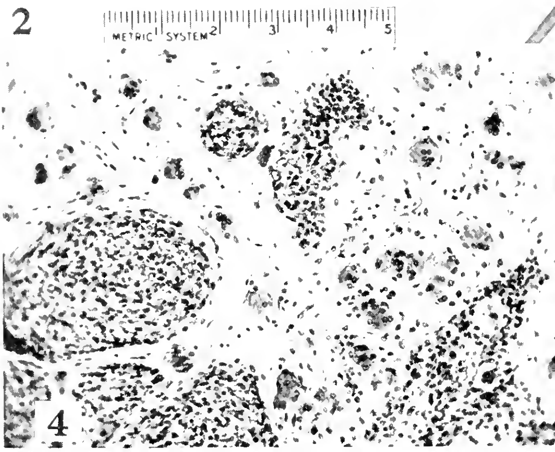

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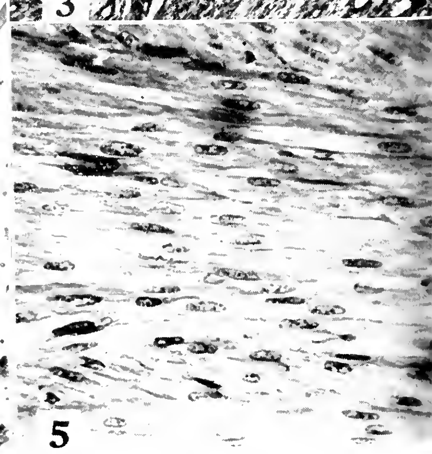

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PLATE XII

In the case of multiple papillomatosis, numerous small gray nodules, some hemorrhagic, were found on the mucosa of the crop and esophagus adjacent to the crop. The wall of the crop was somewhat thickened, about 6 mm. across in the thicker portions. The lesions consisted of papillary projections covered with stratified squamous epithelium (Plate IX, Figure 1). There was in addition a polyblastic infiltration in the submucosa. The chicken was in fair flesh and the only symptom of disease was a slightly distended crop.

A feather follicle adenoma had been noted as a swelling on the head of a chicken for one month before the bird was killed. The swelling had been breaking open and bleeding at different times (during the interval between the time it was first noted and necropsy). On section, the swelling was found due to a mass of well-vascularized, encapsulated, gelatinous tissue measuring 10 mm. in diameter by 6 mm. thick, which was confined to the subcutis and attached to the skin. Histologically the mass was composed of cells arranged in a syncitium and resembled very much the cells found at the base of feather follicles.

A foetal adenoma of the thyroid was found in a chicken killed because of infection with infectious laryngotracheitis. The left thyroid measured 40 × 35 × 25 mm. and contained a few cysts filled with dark green semi-fluid material. The bulk of the affected thyroid was found to be made up of foetal thyroid tissue, small, compressed acini of cells with no lumen (Plate VIII, Figure 2). There were a few dilated acini whose lumen contained pink-staining colloid mixed with much cellular debris. The right thyroid was normal. A small melanoma was also found in this case near the base of the tongue.

In the majority of cases of epithelial neoplasia examined, the chickens were killed. The average age was 67.1 weeks at the time of necropsy although there was considerable variation (range from 12 to 258 weeks). Neoplasia was an incidental finding in seven cases, the majority of which were relatively young birds. One bird in this group was 228 weeks old at the time of examination; but if this bird is disregarded, the average age of the birds in which neoplasia was an incidental finding was only 28 weeks. In 10 birds the tumor was the principal reason for examination, and the average age of this group was considerably older (54.2 weeks, with elimination of one bird which was 258 weeks old).

Legend for Plate XII

Figure 1. S 253. Carcinosarcoma. A loop of intestine has been spread out to show the heavy, diffuse implantation of tumor on the serous surface of the mesentery.

Figure 2. Case 1898. Leiomyoma in mesosalpinx. The entire oviduct and ventral mesosalpinx together with the nodular tumor mass is so arranged as to illustrate their relationship. This specimen is a relatively small tumor.

Figure 3. Q 1621. Carcinosarcoma. The histological section was prepared from an implant of the tumor on the serosa of the mesentery of the pancreas. Many irregular acini of epithelial cells are apparent. The malignant appearance of the stroma of the connective tissue elements is also obvious. Magnification × 85.

Figure 4. T 141. Rhabdomyoma in muscle of thigh. Both loose and compact arrangement of the tumor cells is evident. Several giant cells of the plasmodium type are scattered about in the loosely arranged portion. The tumor metastasized to the wall of the intestine. Magnification × 140.

Figure 5. T 170. Leiomyoma of mesosalpinx. The cells of a single bundle are arranged in a parallel fashion. The pale staining elongate nuclei with rounded ends may be noted. Magnification x 285.

Data on egg production were available on only three of the cases. The bird of case T 74, affected with carcinoma of the ovary, laid 518 eggs in 1244 days of production. Her production index was 0.416 or slightly below the average of the flock. Her last egg was laid 116 days before necropsy. The hen of Case 758 laid 720 eggs in 1600 days of production for a production index of 0.450, also slightly below average. The last egg was laid 205 days before necropsy. The bird affected with papillary cystadenoma of the gizzard (case T 130) laid 235 eggs in 363 days of production. The production index of 0.648 was relatively high. Her last egg was laid 54 days before necropsy.

Hepatoma

Small hepatomas were noted in the livers of three chickens as a finding incidental to other unrelated pathology. These islands of slowly proliferating liver cells were regarded as neoplastic because of their solitary occurrence and because of lack of evidence for liver damage that might have stimulated focal regeneration of the liver.

1. T 210. A $5\frac{1}{2}$-month-old pullet died showing acute focal necrosis of the liver. A pendunculated nodular mass measuring 25 × 20 × 15 mm. was found attached by a broad base 15 mm. in diameter to the visceral aspect of the left lobe of the liver. The mass was darker than the liver and somewhat hemorrhagic.

2. T 301. A 7-month-old pullet suspected of pullorum disease was killed for examination. A firm, rounded tumor mass approximately 2.5 cm. in diameter was found near the surface of the left lobe of the liver.

3. Case 438. A 5-month-old pullet was killed for examination because of symptoms of fowl paralysis. Upon necropsy a gray-white nodular mass 18 mm. in diameter was found in the mid portion of the right liver lobe. Lesions of fowl paralysis were present.

The histology of all three cases of hepatoma was similar (Plate XI, Figure 1). The neoplastic liver cells closely resembled normal liver cells. The arrangement of the cells varied in different portions of the tumor. In some areas they were without definite arrangement; in other areas they formed distinct cords, parallel to an empty channel resembling a liver sinusoid. The liver substance adjacent to the hepatoma was compressed and not infiltrated by the tumor.

From these data hepatoma of the chicken appears to be a rather uncommon neoplasm. Its benign character is indicated by the fact that all of the cases were incidental findings.

Cholangioma

The diagnosis of cholangioma or adenoma of the bile duct was a problem in several cases. The difficulty arose because of the marked connective tissue and polyblastic response that occurred in many of the cases diagnosed as cholangioma. Instances of cirrhosis, hepatitis, and cholangitis were seen in which there was an active fibrosis in the periportal areas coupled with a proliferation of the bile ducts. In some, the proliferation was so extensive as to suggest a neoplastic state. One case of a fibrosarcoma of the liver is described in another section with a similar reaction of the bile ducts. The basis upon which a pathologist may separate a neoplastic from a granuloblastic process is rather arbitrary under such conditions. It is, of course, possible that the neoplastic condition might arise from a process that in the beginning was only a granuloma. Except for the reports of Goss (11) and Eber and Malke (4), biliary carcinoma of the chicken is not often discussed in the literature. Unfortunately no description is given of the cases mentioned in these reports. It is worth while, therefore, to present a brief description of the four cases of cholangioma found in this collection.

1. T 143. An 8-month-old pullet affected with chicken pox was killed for examination. The liver was moderately enlarged by the presence of numerous areas of hemorrhage, particularly common in the right lobe. The hemorrhages were not fresh and were only partly organized. The largest area of hemorrhage was approximately 2 cm. in diameter. In the substance of the right lobe of the liver was an oval mass of firm, gray tissue measuring 9 × 5 mm. Histologically this mass was composed of numerous irregular acini of bile duct epithelium between which were arranged bundles of fibroblasts and irregular areas of myelocytes and polyblasts. The other necropsy findings were essentially negative except for a few shallow, chronic ulcers in the ileum. No explanation for the hemorrhages in the liver could be found. Fowl leukosis was suspected but the bone marrow though somewhat scant in amount was in a hyperplastic and not neoplastic state.

2. T 286. A 33-week-old pullet was found dead. In the right lobe of the liver was a gray-red-brown mass rather sharply defined and somewhat firmer than the adjacent hepatic tissue. The mass measured 20 × 22 × 25 mm. and consisted of irregular acini and tubules of low cuboidal epithelium between which were many lymphoid cells and a few connective tissue fibers (Plate XI, Figure 3). There was a rather marked degree of fatty metamorphosis in the neighboring hepatic cells.

3. Case 283. This bird died at the age of 61 days with erythroblastic leukosis induced by inoculation with material of a transmissible strain of the disease. A small gray nodule of tumor tissue was found in the substance of the right liver lobe. The tumor was composed of epithelial cells, which for the most part were without definite arrangement, although in some areas irregular acini were formed.

4. T 242. A 12-month-old pullet with fowl pox was killed for examination. The pox lesions involved a rather extensive area over the abdomen and sternum. Pathology of the visceral organs was limited to the liver in which were several irregular areas of gray tissue scattered in both lobes. Only one mass in the right lobe was apparent in the intact specimen. The others were found upon cross section. The tumor masses were intimately associated with the larger blood vessels. The largest mass was 10 mm. in diameter. Numerous acini and irregular tubules of bile duct cells were found in the tumor. Between the epithelial elements was a dense infiltration with lymphoid cells and a light, scattered infiltration with heterophils. A rather marked fatty metamorphosis of the liver cells was found.

Cholangiomas in these cases were either single or multiple. All were found in female chickens but the number is so small that this fact has little significance. The ages of the birds at the time of examination ranged from two months to a year. From the data, it would seem that cholangiomas are benign neoplasms. Although the cholangioma found in Case 4 must be considered an incidental finding, its multiple nature suggests that with more time for development it might have been a primary cause of death.

Thymoma

Two cases of tumor were diagnosed as thymoma. There was a distinct similarity of the macroscopic and microscopic features in both cases.

1. T 19. A 9-month-old pullet was found dead with a marked swelling of the throat in the region of the crop. Upon necropsy the swelling was found to be due to an irregular tumor mass at the base of the neck on the left side. The mass measured approximately 8 × 5 × 3 cm. and was relatively firm and grayish pink in color. The tumor lay in the left jugular furrow, infiltrated the adjacent soft structures, and closely enveloped both the trachea and esophagus. In general the tumor seemed to grow upward in the neck although there was a small projection beginning to enter the thoracic aperture. Deposits of urate crystals were found in the pericardial sac, and both kidneys were slightly swollen and pale in color, suggesting that death may have been due to a kidney insufficiency rather than to the tumor. Other visceral organs were essentially normal. Microscopic study indicated that the principal components of the tumor were polymorphous cells larger than the thymic lymphocytes seen in a normal thymus. These cells

were round, oval, or polyhedral and possessed a relatively large vesicular nucleus in many of which nucleoli could be distinguished. The polymorphous cells were supported by a well-developed framework of anastomosing reticulum cells similar to those seen in a normal thymus. Scattered throughout the tumor were peculiar large cells with an opaque acidophilic cytoplasm and relatively small vesicular nuclei. Their appearance was that of giant cells, although multinucleated forms could not be found. In a few places the reticular stroma cells clumped themselves together in such a manner as to suggest an attempt to form a structure like a Hassell's corpuscle.

Although the tumor was well supported by fibroblasts, it was not confined by a capsule. It readily infiltrated the adjacent soft tissues including the musculature. The muscles of the trachea were infiltrated but the annular cartilages seemed to be an effective barrier to further invasion of the structure.

2. T 306. A very fat year-and-a-half-old hen was found dead. Death was apparently due to hermorrhage from rupture of the liver capsule, the cause of which could not be determined. A tumor mass was found in the right jugular furrow in the mid-cervical region and was apparently derived from the thymic node of that location. The tumor measured $3 \times 3 \times 2.5$ cm., was reddish gray-white in color, and was relatively firm. On cross section, small cysts filled with clear fluid were noted. Other nodes of the thymic chain were fairly well developed and a representative node anterior to the tumor measured $10 \times 5 \times 2$ mm. No other significant pathology was found. The histology of the tumor was similar to that described in the first case (Plate IX, Figure 2). The cyst-like structures were interpreted as obstructed and distended lymph channels.

A thymoma of the chicken has been described by Feldman (6) and the two cases above seem very similar to his. These tumors of the chicken show a granulomatous character coupled with the invasiveness of a neoplasm, which leads to the question of whether or not they should be considered as a neoplasm. Ewing (5) discusses this question with regard to thymomas of man and comes to the conclusion that they should be regarded as infectious granulomas.

Hemangioma

Neoplasia classified as hemangioma was found in five instances. The type cell of a hemangioma is the angioblast, which tends to form new blood spaces or channels. Sometimes the channels formed by the tumor are of capillary size and the term "capillary hemangioma" is descriptive. At other times the tumor tends to form large blood spaces, for which condition the term "cavernous hemangioma" is used. Some authors favor the term "hemangio-endothelioma" in preference to hemangioma (Feldman 7). Both capillary and cavernous forms of hemangioma were found in this collection. Although certain data on the cases are presented in Table 16, a brief description of each will provide a better conception of the cases.

1. Case 444. Some details of this case have been described previously (Olson 23). The chicken was found dead in its pen. Examination of the blood made 46 days previously had shown no significant changes. A slight relative eosinophilia was noted 39 days previous to death; and 25 days preceding death a moderate, relative, heterophil leukocytosis was observed. A swelling of the left foot pad was noted about a week before the bird died, and on the day before death the chicken was weak, dull, and listless. The carcass was emaciated. The swelling of the left foot pad was soft and fluctuating and on section was found to be composed of clotted blood and what appeared upon gross examination to be granulation tissue. The liver was slightly swollen, was red brown in color, and contained numerous foci of clotted blood under the capsule and deep in the substance of the organ. Similar foci of accumulated blood were present in the kidneys, lungs, heart, and spleen. The spleen was enlarged (2 cm. diameter) and consisted principally of an ancient blood clot. Splenic tissue was confined to a narrow crescentic border along one edge of the mass representing the spleen. The foci of blood in the heart muscle and in the kidney seemed to have a thin though distinct surrounding membrane. The blood in the heart chambers was not clotted. No pathological changes could be noted in a smear prepared from the

heart's blood. The histology of the tumor was portrayed best in foci in the heart and lung. The type cell was the angioblast. In some areas these were compact and in others they tended to form small spaces which were filled with blood. The lining of the larger blood spaces was stretched thin. In many of the larger blood spaces the blood was coagulated and varying degrees of organization were apparent. Although no section was made of the tissue surrounding the blood clot in the left foot pad it is possible that this lesion represented a focus of tumor.

2. Case T 291. The bird was thin and inactive when killed for necropsy. The liver was markedly enlarged, with a somewhat greater relative enlargement of the right lobe. Numerous areas of coagulated blood of variable size were scattered throughout the substance of the organ. A few similar masses of clotted blood were found in the anterior pole of the right kidney. Sections prepared from the liver revealed a histology so altered that the tissue could scarcely be recognized as liver. The bulk of the parenchyma was replaced by neoplastic cells which tended to form walls enclosing masses of blood. In some areas the tumor cells were in a sheetlike, syncitial arrangement without definite order. An irregular, patchy granulocytic infiltration was evident throughout the liver. Neoplastic angioblasts were found around the blood clots in the kidney. The bone marrow and spleen were found negative upon histological examination.

3. Case T 46. A tumor mass was found in a bird which the owner had killed and dressed for food. The carcass was in good flesh and the bird had shown no symptoms of disease. The tumor mass, which measured 35 × 25 × 20 mm. and weighed 150 grams, was found attached to the ovary. The ovarian tissue itself was inactive and appeared normal. The tumor was dark red with irregular yellow areas. The colors were obviously due to coagulated masses of blood in various stages of organization. Upon section, the masses of blood were found surrounded by a membrane formed of a thin, stretched angioblast type of cell. Between the large masses of blood, the tumor cells tended to form small capillaries, some of which did not contain blood in the lumen. Histological section of the normal-appearing part of the ovary revealed no pathology.

4. Case T 98. A bird with a respiratory infection was killed for examination. An incidental finding was a small (2 mm. in diameter), gray nodule beneath the capsule of the left lobe of the liver. This nodule was made up of imperfectly formed capillaries, a few of which contained blood cells in their lumens. Interspersed between the vessels were many granulocytes.

5. Case T 280. The bird providing material for this case was affected with histiocytic sarcoma and is described in the section dealing with that form of neoplasia. The histiocytic sarcoma was confined to the subcutis of the pectoral region and both lungs. A small gray mass was noted beneath the capsule of the liver. On section, this proved to be an area composed of angioblasts forming fairly well developed capillaries (Plate XI, Figure 2).

Three of the five cases of hemangioma described may be considered as the cavernous form and the other two as the capillary form (Table 16). Only two of the cases (Cases 444 and T 291) were malignant as indicated by extent of the tumor growth. Both of the cases regarded as malignant were of the cavernous form, and in these birds the lesions were responsible for serious illness. The small

TABLE 16.—DATA ON FIVE CASES OF HEMANGIOMA

Case No.	Age (Weeks)	Sex	Location of Tumor	Form of Tumor
444	*D 22	Female	Liver, kidneys, lungs, heart, spleen	Cavernous
T 291	K 28	Female	Liver, kidney	Cavernous
T 46	K 52	Female	Ovary	Cavernous
T 98	K 32	Female	Liver	Capillary
T 280	K 28	Female	Liver	Capillary

*D indicates that bird died; K, that it was killed for examination.

lesion in the liver of two of the cases might easily have been overlooked. It is of interest to note that the liver was affected in four of the five cases studied, which suggests a predilection of the liver of the chicken for development of hemangioma.

Lymphangioma

Only one case of lymphangioma was encountered. A descripton of the case follows.

1. Case T 264. An 8-month-old, cross-bred female was sent to the laboratory for examination. It was dead upon arrival, and the carcass was in pocr flesh. A considerable excess of fluid was found in the peritoneal cavity, together with fibrinous, yellow debris. Yellow debris and albuminous material were found in the lumen of the oviduct. A tumor mass measuring 5 × 4 × 4 cm. was found attached to the ovary by a long (5 cm.) narrow stalk. The tumor consisted of soft, moist tissue, mottled gray and red in color. The more superficial part contained many small cysts filled with clear fluid. Histologically the tumor was composed of somewhat spindle-shaped cells with anastomosing cell processes. In some areas they lined rather large spaces filled with faint pink staining material (Plate XI, Figure 4). In other areas they exhibited a tendency to form small capillary-like structures. The serous aspect of the tumor and some of the visceral organs showed changes of a chronic fibrinous peritonitis. Illness and death of the bird were probably due to the salpingitis and peritonitis, and the tumor was an incidental finding disclosed only by necropsy of the bird.

The histology of the tumor was very similar to that observed in some of the cases of hemangioma, except that no blood cells were found enclosed in spaces formed by the neoplastic cells.

Leiomyoma

Thirty-four leiomyomas or tumors composed of smooth muscle cells were found. They were firm, tough, and fibrous in consistency, and on cross section appeared to be made up of interlacing bundles of tissue (Plate XII, Figure 5). The tumors were usually somewhat encapsulated, were spherical or oval in shape, and varied in size from a few millimeters to several centimeters in diameter. The largest leiomyoma in the collection weighed 368 grams.

The smooth muscle tumors were found only in female chickens. The most common site for the tumor (27 cases) was the ventral ligament of the oviduct at approximately the mid-portion (Plate XII, Figure 2). In five cases the tumor was in the wall of the oviduct; in one case tumor was found in both the mesosalpinx and the oviduct; and in one case the location could not be determined as the specimen consisted of a tumor mass which had been "found in the abdominal cavity of a hen." In only one case was there spread or metastasis of the tumor. In this instance the primary tumor was in the ventral ligament of the oviduct and metastatic foci of the tumor were found in the liver and breast muscle.

Leiomyomas are classified according to the time of year they were observed, as follows: first quarter, 6 cases; second quarter, 10 cases; third quarter, 13 cases; and fourth quarter, 5 cases. The average age of birds with leiomyoma was 61 weeks (range 26 to 107 weeks) for 15 birds that were killed for examination, and 71 weeks (range 37 to 106 weeks) for 19 birds that died.

In practically all cases, the leiomyoma was an incidental finding at the time of necropsy. In no instance was such a tumor reponsible for specific symptoms of the disease.

Egg production records were available on 18 of the birds affected with leiomyoma. These data are given in Table 17 and indicate that the birds were well above average in their ability to produce eggs. The average production

index for the entire flock from which these chickens came was, as previously indicated, 0.534 for the first 150 days of productive life. For the group with leiomyoma, the index was 0.615, with a range from 0.418 to 0.810, and only five hens had an index below the average of the flock. These figures become even more significant when it is considered that the production index for the group with leiomyoma was calculated for a period extending beyond the first 150 days of production, which is the period of heaviest egg production. The interval between the last egg laid and necropsy averaged only 12 days, with a range from 1 to 73 days. Such a short interval would seem to indicate that the slow-growing leiomyoma interfered but little with egg production.

TABLE 17.—DATA ON EGG PRODUCTION OF CHICKENS WITH LEIOMYOMA.

Productive life is the interval between first and last eggs laid.
Production index is the factor obtained by dividing the number of eggs laid by the productive life in days.

Case No.	Age at Necropsy (Days)	Productive Life (Days)	Number of Eggs Laid	Production Index	Interval from Last Egg to Necropsy (Days)	Size of Tumor Average Diameter (mm.)
T 59	*K 457	270	198	734	1	15
T 68	K 479	318	133	418	4	15
T 83	D 523	334	205	614	1	30
T 84	D 511	290	167	576	11	35
T 86	D 524	320	223	697	22	12
T 89	D 534	310	138	445	29	35
T 174	D 743	567	302	533	3	20
T 212	D 487	291	149	512	8	12
T 258	D 549	346	217	627	2	10
**T 493	K 449	264	191	724	2	35
T 854	K 450	276	202	.732	4	12
***T 2207	D 442	249	158	.634	3	28
T 667	D 435	246	152	.618	1	30
T 1606	D 364	195	158	810	1	10
***S 1129	D 743	472	233	494	73	10
T 283	D 606	383	270	705	4	22
S 253	K 747	510	249	488	53	20
T 95	D 557	326	231	709	12	25
Average	533	331	190	615	12	21

*K indicates that bird was killed for examination; D, that it died.
**Tumor located in both ligament of oviduct and oviduct.
***Tumor located in oviduct only.
In all other cases, tumor located in ventral ligament of oviduct.

The location of leiomyoma in the ligament of the oviduct and the heavy egg production of chickens with this tumor lead to speculation of a causal relationship. The report of Curtis (2) outlines well the musculature of the ligaments of the oviduct, which is greater in amount in the ventral ligament than in the dorsal ligament. Curtis indicated that the smooth muscle fibers of the ligaments were directly connected with the muscle fibers of the wall of the oviduct and that musculature in the ligaments must contribute to the physiological motility of the oviduct. Greatest activity would occur during periods of egg production and

when persistent might reasonably lead to hypertrophy of the muscles. Jackson (13) has called attention to the predisposition of smooth muscle in the ovary and oviduct for proliferation. Sometimes this hypertrophy appears to progress beyond functional requirements, thus leading to the development of a benign neoplasm. Other factors must also be involved, for all hens with prolonged, heavy egg production do not necessarily develop a leiomyoma of the mesosalpinx and there was no direct correlation between the size of the tumor and production index in this series.

Two birds with leiomyoma also had carcinoma of the ovary, and four others with smooth muscle tumors had mixed tumors (carcinosarcoma) of the ovary. The latter four cases are discussed in more detail in the section dealing with carcinosarcoma.

Rhabdomyoma

Tumors derived from voluntary muscle tissue are usually considered rare, and indeed but few cases in the chicken have been described. Eber and Malke (4) mentioned finding multiple rhabdomyoma in a poorly developed breast muscle of a hen, and Reitsma (28) described a case in which multiple tumors were found in the muscles of the maxilla, thorax, and abdomen. Peyron and Blier (26) described a malignant myoma the size of an apple found in the leg of a rooster.

Two cases of neoplasia were diagnosed as rhabdomyoma in this study.

1. T 303. An 8-month-old male, lame on the right leg, was killed by the owner and submitted for examination. Isolated multiple tumors were found enclosed within the sheaths of several muscles. These were found in the flexor and extensor muscles in both thighs, in both pectoral muscles, and in muscles on both sides of the thorax at the level of the second and third ribs. The largest tumor measured 25 mm. in diameter and 35 mm. in length and was found in an extensor muscle of the left thigh. The tumors were spindle-shaped, conforming in general to the shape of the affected muscle. A striking feature was the bilateral symmetry of location of the individual tumor masses. The visceral organs and peripheral nerves were normal. The tumors were of a similar histological composition. Malignant spindle-shaped cells replaced the muscle tissue although bundles of degenerating muscle fibers were scattered in some areas. The tumor cells were relatively long with tapering ends when viewed in longitudinal section, and a very fine fibrillary character of the cytoplasm was noted. On cross section, the cells were round and, when cut through the nucleus, the latter occupied approximately one-fourth the space of the cell. Longitudinal or cross striations were not noted in sections stained with the routine hematoxylin and eosin combination. The nuclei of the tumor cells were elongate and somewhat vesicular. Mitotic figures were infrequently noted. The cells lay in rows parallel to each other but did not tend to arrange themselves in compact bundles although in some instances the cell processes seemed to anastomose with adjacent cells. A fibroblastic stroma with well-developed collagen fibers formed a supporting framework for the tumor. A Van Gieson's preparation of sections of the tumor indicated the myogenic character of the tumor cells, as the cytoplasm had the staining property of muscle tissue.

2. T 141. The bird providing material for this case was a 10-month-old pullet which had given a suspicious reaction to a test for pullorum disease and was killed for examination. An irregular tumor mass measuring 20 × 15 × 7 mm. was found in the posterior edge of the semitendinosus muscle at about the middle of the thigh. The tumor was white and relatively firm. Another small tumor nodule was found on the wall of the small intestine opposite its mesenteric attachment. In cross sections of the muscle tumor the connective tissue forming the sheaths of the secondary and tertiary bundles was increased in amount and restricted lateral growth of the tumor. At the edges of the affected secondary and tertiary bundles were degenerated muscle fibers, the majority of which had been replaced by the tumor. The tumor tissue itself was variable in different areas (Plate XII, Figure 4). In some areas the cells were rather plump and widely separated by amorphous intercellular material. In other areas the cells were more compact. In general the cells were elongate and had a fine character-

istic fibrillary structure of the cytoplasm which tended to fray at the ends so that the extreme ends of the cells were indistinct. Cells in the more compact areas lacked the fibrillary character of the cytoplasm. Many of the tumor cells were grouped in small parallel bundles, and oftentimes were noted to be concentrically arranged about an atrophic bundle of muscle fibers. Numerous giant cells were scattered about. These were not the usual form of giant cell noted in the reaction to a foreign body. Instead the multiple nuclei were similar to those of the elongate tumor cells and the cytoplasm had the fine fibrillary structure noted also in the other tumor cells. These cells appear to be similar to the plasmodium type of giant cell described in some cases of rhabdomyoma found in the human (Rakov 27). Section of the tumor in the wall of the intestine revealed it to be composed of cells similar to those in the more compact part of the muscle tumor. They tended to arrange themselves in a syncitium with anastomosing cell processes. At the edge of the tumor they seemed to join and blend themselves with the musculature of the wall of the intestine, a considerable portion of which they actually replaced. Van Geison's preparations were made of both tumors and a definite reaction of the tumor cells could not be obtained to identify them as of muscular origin. No striations could be identified in the cells of either tumor.

The diagnosis of these two cases as rhabdomyoma requires some comment. Tumors derived from muscle tissue are commonly grouped under the term myoblastoma in a simple classification of tumors. The group is further subdivided into leiomyoma for those tumors derived from smooth muscle tissue and rhabdomyoma for those tumors derived from voluntary or striated muscle tissue. It is generally recognized that longitudinal and cross striations are a characteristic of voluntary muscle and their presence in tumor cells derived from muscle provides a simple, easy means of diagnosing a rhabdomyoma. These cannot always be demonstrated; for example, in 17 malignant rhabdomyoblastomas of man studied by Rakov (27) cross striation of the cells could not be demonstrated in 9. Cappell and Montgomery (1) discuss this difficulty and suggest that tumors derived from striated muscle be classified as rhabdomyoma when cross striations can be demonstrated and as myoblastoma when they cannot be shown. This conception would not permit classification of leiomyomas under myoblastoma as is commonly done.

The two cases of tumor described above seem quite clearly to have originated from voluntary muscle tissue. In one case the morphology of the cells and their staining reaction were characteristic. In the other case the typical staining reaction could not be demonstrated, yet the morphology of the ribbonlike cells, the fibrillary appearance of the cytoplasm, and polymerphism were very similar to that described in rhabdomyoma found in man. Both cases might be considered simply as myoblastomas; yet in view of their probable derivation from striated muscle, the term rhabdomyoma is applied to conform to the more simple classification of tumors.

Mesothelioma

One case of the series was considered a mesothelioma.

1. Case T 157. This was an active, 9-month-old pullet whose only symptom of disease was distension of the abdomen. The bird was killed for necropsy. Approximately 700 ml. of green-tinted yellow fluid was responsible for the abdominal distension. Two tumor masses were found in the abdomen. The smaller mass was situated on the serosa of the posterio-ventral aspect of the abdomen and attached by a stalk to a larger mass which in turn was connected by another stalk to the body wall in the vicinity of the ovary. Both stalks consisted principally of blood vessels. The larger tumor measured 5.5 × 4 × 3 cm. and weighed 37 grams. The smaller tumor weighed 12 grams. Both tumors were vascular and gray-white in color. They were irregular in shape, relatively soft, and contained small areas of necrosis. A few small cysts filled with clear fluid were noted in the smaller tumor, to which were also attached some pendulous cysts filled with organized blood clots. The visceral serosa was somewhat thickened and the

intestinal loops were attached to each other by firm adhesions. The ovary was inactive and the visceral organs otherwise normal.

The histology of the tumor was somewhat variable. The bulk of the mass was made up of sheetlike masses of moderate-sized oval or polyhedral cells with rather pale, round nuclei (Plate IX, Figure 4). In some parts the cells assumed a cuboidal form and arranged themselves in rows, and in other areas they were compressed to a spindle form. Areas of hemorrhage and necrosis were found. The visceral serosa was thickened by a fibrinous covering in which some organization had taken place.

Melanoma

As mentioned in the section dealing with epithelioblastoma, a small melanoma was found at the base of the tongue in a bird which also had a foetal adenoma of the thyroid. Both of these tumors were incidental findings in a bird killed for examination because of laryngotracheitis infection.

1. Case T 101. The bird was a 6-month-old female. The melanoma consisted of a small, encapsulated mass situated in the loose areolar tissue on the ventral surface of the hyoid bone at the base of the tongue. It attracted attention because of its black color. The tumor was round and somewhat flattened, measuring 5 mm. in diameter and 2.5 mm. in thickness. Histologically it consisted of a rather compact mass of cells which appeared to be arranged in the form of a syncitium. The nuclei varied in size, but in general they were relatively large, vesicular, and contained distinct nucleoli. There was a variable amount of black pigment in the cytoplasm of the cells. In some cells this was arranged in the form of very fine dustlike particles; and in others the granules were coarse, in some instances entirely obliterating the cell structure (Plate VII, Figure 4). In general the tumor did not appear to be actively growing and it may be regarded as a benign tumor.

Embryonal Nephroma

Embryonal tumors of the kidneys of the chicken are usually composed of a mixture of epithelial and connective tissue elements and probably arise as result of a defect in development of the kidney. There were 21 cases of embryonal nephroma in this series of tumors of the chicken, 11 of which were females and 10 were males; a sex ratio of 1 to 1. The average age at necropsy was 27.2 weeks (the youngest case died at 7 weeks and the oldest case was killed for examination at 50 weeks). Eight of the group were killed at an average age of 19.4 weeks and the remaining 13 died at an average age of 32.1 weeks. These cases were somewhat younger than those reported in the literature. For example, Mathews (18) described a series of 12 cases, 9 of which were in birds between 9 and 24 months old.

The tumor masses were all confined by either the capsule of the kidney or a well-developed capsule of their own. The size and shape of the tumors varied considerably (Plate X, Figures 1 and 2). In two instances, no tumor was apparent at the time of necropsy and its presence was revealed only by histological examination of the kidney. The largest tumor weighed 299 grams and had completely replaced the kidney. Embryonal nephroma was associated with cysts of the kidney in four instances. The histological appearance of the cases was likewise variable, although both connective tissue and epithelial constituents were present in all. The variations were principally in the relative amounts of these elements (Plate X, Figures 3 and 4). Keratinization and epithelial pearls were found in six tumors, although in none was this process as well developed as in the case described by Feldman and Olson (9). In one instance of a unilateral mass arising from the left kidney, there were many areas of cartilaginous tissue.

The embryonal nephromas were unilateral in 16 of the cases, affecting the left kidney in 7 instances and the right kidney in 7; while in 2 cases the site was

unknown, as only a tumor mass described as coming from the abdominal cavity was available for examination. Both kidneys had foci of embryonal nephroma in 5 instances. It is of interest to compare these findings with those of Mathews (18), for the left kidney only was the site of tumor in the 12 cases described by him. All of the cases studied by Mathews had shown symptoms of paralysis of the left leg as a result of pressure on the nerves caused by the tumor mass. Similar symptoms were noted in three of the cases in this study.

Lymphocytoma was an associated finding in four cases of embryonal nephroma, myelocytoma was present in one case, and fowl paralysis in one. One bird with embryonal nephroma was found to be also affected with a hormonal disturbance in which a change in plumage from female to male type had occurred. An ovariotestis was found which was probably responsible for the condition, as described by Lipschütz (15) under the subject of intersexuality of birds. Friedgood and Uotila (10) have studied such cases of virilism and believe the term "arrhenoblastoma" should be used when this type of tumor is encountered in the chicken.

Carcinosarcoma

Neoplasms composed of both malignant epithelial and malignant connective tissue elements, or mixed tumors have been diagnosed as carcinosarcoma in this survey. These interesting tumors offer much more material for study and comment than can be adequately covered in this brief discussion. The pathogenesis of carcinosarcoma would be an interesting subject for detailed study.

The diagnosis of carcinosarcoma was made in seven cases of neoplasia encountered during the course of this survey. A short description of the pertinent pathology of each will give a better picture of the disease than a general discussion.

1. T 95. A 20-month-old hen was found dead. Numerous small, firm, gray-white nodules a few millimeters in diameter were scattered over the peritoneal surfaces of the viscera, particularly concentrated about the pancreas. A firm, tough, fibrous tumor mass was found in the ventral ligament of the oviduct and proved to be a leiomyoma. A cross section through the pancreas showed the pancreatic tissue to be markedly compressed and reduced by an encircling mass of neoplastic tissue consisting principally of fibroblasts and a few well-defined epithelial elements which tended to form tubules and acini. At one point the musculature of the duodenum was penetrated and the tumor infiltrated the submucosa. Epithelial elements of the tumor were much more in evidence in the peritoneal implants of the tumor. Van Gieson's picric acid fuchsin method for differentiating between connective tissue and muscle fibers was applied to the tumors. The tumor of the mesosalpinx was made up entirely of muscle fibers. The mixed tumors of the serosa contained a small amount of muscle fibers in addition to the connective tissue and epithelial elements.

2. T 239. A hen died at the age of 19½ months. A firm, tough, fibrous mass measuring 50 × 30 × 30 mm. was found in the ventral ligament of the oviduct. The mass was well encapsulated and consisted of neoplastic smooth muscle cells. On the visceral surface of this tumor was a small area of carcinoma. The serosa of the viscera was covered with many small, white, firm nodules that tended to become confluent in many areas, especially over the pancreas and duodenum and in the ileocecal ligaments. These nodules represented mixed tumors composed of epithelial cells and connective tissue with varying amounts of each in different locations. A Van Gieson's preparation indicated the absence of muscle tissue in the mixed tumor.

3. T 283. The hen was about 22 months old at the time of its death. A marked ascites was present (approximately 450 ml.) consisting of slightly turbid straw-colored fluid. A rounded, firm mass, 22 mm. in diameter, was found in the ventral ligament of the oviduct, which proved to be composed of smooth muscle cells. There were two small nodules about 5 to 7 mm. in diameter on the visceral aspect of the oviduct 2 cm. from the cloacal orifice. The serosa of the visceral organs was covered with many small, firm nodules, confluent in some areas and

particularly common about the duodenum and pancreas and ileocecal ligaments. The smaller nodules of tumor on the oviduct and serosa were composed principally of epithelial elements, varying in different sites from undifferentiated carcinoma cells to fairly well organized glandular structures. Another element of the smaller nodules was compressed spindle-shaped cells. The majority of these spindle-shaped cells gave the chemical reaction of connective tissue with the Van Gieson method. Scattered throughout and intermingled with the connective tissue fibers were a few cells which had the distinctive yellow color of muscle cells.

4. S 253. A hen, 27 months old, was killed for examination because of a large pendulous abdomen. The enlargement of the abdomen was found to be due to the accumulation of approximately 800 ml. of ascitic fluid. Numerous small, firm nodules were scattered on the visceral peritoneum (Plate XII, Figure 1). The ovary was represented by an irregular mass of firm nodules. The tumors on the peritoneum and the ovarian tumor were found to be made up of both epithelial acini and connective tissue cells, among which were scattered a few cells with the tinctoral properties of muscle tissue. A leiomyoma, 20 mm. in diameter, composed of muscle cells only was found in the mesosalpinx.

5. S 36. A 26-month-old hen was killed for examination because of general symptoms of debility. A marked ascites was found. The mesentery was covered with nodular, firm, gray-white tissue and the ovary was represented by a mass of similar tissue. The neoplasm consisted of epithelial cells forming small imperfect acini supported by a framework of compressed spindle-shaped connective tissue cells, among which were scattered small irregular collections of smooth muscle cells.

6. Q 1621. The hen died at the age of 55 months. The carcass was emaciated. An irregular tumor mass of the mesentery and thickening of the wall of the intestine had caused an almost complete obstruction to the lumen of the duodenum. The ovary was involved with a similar tissue and measured approximately $50 \times 45 \times 30$ mm. The neoplasm was made up of carcinoma cells forming irregular tubules and acini, connective tissue cells, and a few smooth muscle cells (Plate XII, Figure 3).

7. Case 922. A 31-month-old hen with a distended abdomen was killed for examination. A marked ascites was present. Two multilocular cysts were found in the abdominal cavity, which seemed to be attached to the mesentery. Many small, firm nodules were scattered on the serosa of the viscera. Both adrenals were enlarged and infiltrated with gray tissue. The tumor consisted of a mixture of adenocarcinoma and spindle-celled sarcoma tissue. Van Gieson's preparations indicated scattered collections of muscle cells among sarcoma cells of the connective tissue framework. This case has been previously described (23), and at that time the possibility that the tumor had arisen from displaced embryonic mesonephric tissue was considered. The character of the tumor and the involvement of the adrenals cause the case to be different from the other carcinosarcomas described above.

Information on egg production was available on five of the cases of carcinosarcoma. The data are listed in Table 18. The hens were good producers, the average index of production being 0.575 which is higher than the index of 0.534 for the flock from which these birds were derived.

All of the birds affected with carcinosarcoma were of advanced age, ranging from approximately 78 to 220 weeks at the time of examination, and averaging about 115 weeks in age. As a group they are the oldest represented among the various forms of neoplasia. The next oldest group was those birds affected with carcinoma, with an average age of 75.5 weeks.

These tumors which have been grouped as carcinosarcomas may be regarded as an entity for the purpose of classification. A feature common to all the cases was the widespread implantation of the mixed tumors on the serosal covering of the viscera, as well as the marked proliferative activity of the sarcomatous elements. The ovary, pancreas, and adrenal were the only visceral organs affected by the tumor and it would appear that the epithelial elements of the tumor must have been derived from these organs. In three cases the ovary alone was affected

Table 18.—Data on Egg Production of Chickens with Carcinosarcoma.

Productive life is the interval between first and last eggs laid.

Production index is the factor obtained by dividing the number of eggs laid by the productive life in days.

Case No.	Age at Necropsy (Days)	Productive Life (Days)	Number of Eggs Laid	Production Index	Interval from Last Egg to Necropsy (Days)
S 36	*K 730	528	255	483	24
Q 1621	D 1542	1197	584	.485	149
**T 283	D 606	383	270	705	4
**S 253	K 747	510	249	488	33
**T 95	D 557	326	231	709	12
Average..	836	589	318	575	44

*K indicates that bird was killed for examination, D that it died.
**Also leiomyoma in mesosalpinx.

and must be regarded as the primary site of origin; the same applies for the pancreas in two cases and the adrenal in one. In the remaining case both the ovary and pancreas were involved. An interesting and complicating factor was the finding of a leiomyoma of the mesosalpinx in four of the cases. For convenience the distribution of lesions is arranged in tabular form (Table 19).

Table 19.—Distribution in Seven Cases of Carcinosarcoma.

Case No.	Organ or Tissues Affected				
	Ovary	Pancreas	Adrenal	Serosa	Mesosalpinx
*T 95	**Mixed	Mixed		Mixed	Leiomyoma
T 239		Mixed		Mixed	Leiomyoma
*T 283		Mixed		Mixed	Leiomyoma
*S 253	Mixed			Mixed	Leiomyoma
*S 36	Mixed			Mixed	
*Q 1621	Mixed			Mixed	
922			Mixed	Mixed	

*Smooth muscle cells intermingled with connective tissue in substance of tumor
**Tumor composed of a mixture of epithelial and connective tissue.

Jackson (13) has given an excellent description and discussion of a type of disease which he terms "carcinoma leiomyomatosum." Four such cases were found in the collection which he studied. One of Jackson's cases is of particular significance with respect to the pathogenesis of mixed tumors. In this case the adenomatous tumor was believed to have originated in the wall of the oviduct, spread by direct extension to the serous surfaces of the visceral organs, and invaded the substance of the ovary and pancreas. In these locations there was an abundance of neoplastic-like smooth muscle tissue supplying the stroma for the epithelial elements. Tumor foci were also found in the liver, but they were composed only of epithelial elements. On the basis of this case Jackson came to the

conclusion that the epithelial fraction of carcinoma leiomyomatosum was the primary element of neoplasia which was capable of stimulating a local proliferation of pre-existing muscle tissue. Thus the mixed tumor did not spread as such, but only the epithelial part was capable of growing when transplanted to a new site. Nodular foci on the serosa composed of muscular tissue only as well as nodules of mixed tissues were found in another case by Jackson. He explained the presence of pure muscle tumors by endowing the muscular elements with a greater growth energy to the extent that the epithelial elements although originally present were later overgrown and destroyed.

The seven cases of carcinosarcoma here described are different from the cases discussed by Jackson in that the smooth muscle in the mixed tumors was small in amount. The leiomyoma of the mesosalpinx in four of the cases appeared to be identical with that found in old hens with a history of heavy egg production. It does not seem logical to explain their origin as due to a stimulus from an implant of carcinoma which later regressed, for other nodules of pure muscle tissue did not occur. Although in two instances a small amount of epithelial tumor was found at the edge of the leiomyomas of the mesosalpinx, these can not be regarded as mixed tumors but would appear to represent implants of the carcinoma on the serous covering of the leiomyoma. Leiomyoma of the mesosalpinx in birds also affected with another type of tumor is not unusual. Among the 14 cases of carcinoma in this collection were two such instances (T 16 and T 294, Table 15). Two similar cases are listed in Appendix C of the monograph by Jackson (13).

Use of the term carcinosarcoma for this group of tumors may be open to question. The presence of smooth muscle and connective tissue in an apparent stage of neoplasia would exclude the cases from the classification of scirrhous carcinoma. The more abundant amount of connective tissue elements does not permit application of Jackson's term "carcinoma leiomyomatosum." Joest and Ernesti (14) described a case which may be similar to these as "sarcoma carcinomatodes." For the present at least the term carcinosarcoma seems to be appropriate to indicate a tumor made up of mixed elements in which the epithelial part as well as the connective tissue and muscular parts have assumed a state of malignancy.

Teratoma

One case of teratoma was found.

1. Case T 307. A year-and-a-half-old male was killed for examination, and before death had been noted to be weak, depressed, and inactive. The posterior half of the left testis was represented by a large mass measuring 13 × 10 × 7 cm. and the entire structure weighed 606 grams (Plate I, Figure 5). The tumor was well encapsulated and had a glistening irregular surface roughened by nodules. The cut surface of the tumor showed many small scattered areas of dry necrosis. In general the color was gray-white. Many small cysts up to 2 mm. in diameter were noted. Small patches of cartilagenous tissue could be felt when the finger tips were rubbed over the cut surface. The left vas deferens and epididymis could not be located in the region of the tumor. The right gonad was normal. The histology of the tumor was extremely variable with a bizarre mixture of various types of tissue. There were many small islands of well-developed cartilage, numerous irregularly formed acini lined with columnar epithelium. Some of these were distended with granular material and the cells lining such areas had vacuoles (probably secretory) in their cytoplasm. A considerable portion of the tumor was made up of connective tissue cells varying in form from slightly differentiated stellate cells to spindle-shaped fibroblasts.

GENERAL DISCUSSION

Incidence

The material studied provides some information on the incidence of tumors. A number of variable factors influence statistics on this subject, and it is obvious that very few factors likely to affect the rate of neoplasia can be recognized and controlled in material such as that with which we were dealing. Despite these limitations the data are sufficient to merit examination.

TABLE 20.—RELATIVE INCIDENCE OF NEOPLASMS IN COLLECTIONS A, B, AND C CORRELATED WITH SOURCE.

Type of Neoplasia	A		B		A and B Combined		C	Entire Series	
	Number of Cases	Percent of Birds Examined (1781)	Number of Cases	Percent of Birds Examined (523)	Number of Cases	Percent of Birds Examined (2304)	Number of Cases	Number of Cases	Percent of Total Neoplasms Found (384)
Lymphocytoma	112	6.29	36	6.89	148	6.41	65	213	55.5
Leiomyoma....	11	.62	21	4.02	32	1.39	2	34	8.9
Embryonal nephroma...	13	.73	1	.19	14	.61	7	21	5.5
Myelocytoma..	14	.78	3	.57	17	.74	3	20	5.2
Leukosis......	14	.78	3	.57	17	.74	2	19	4.9
Epithelioblastoma...	10	.56	7	1.34	17	.74	0	17	4.4
Fibrosarcoma..	12	.67	2	.38	14	.61	2	16	4.1
Carcinosarcoma	2	.11	5	.96	7	.30	0	7	1.9
Neurogenic sarcoma....	3	.17	0		3	.13	2	5	1.3
Hemangioma...	4	.22	0		4	.17	1	5	1.3
Fibroma.......	3	.17	1	.19	4	.17	1	5	1.3
Cholangioma...	3	.17	0		3	.13	1	4	1.0
Hepatoma.....	2	.11	0		2	.09	1	3	.79
Histiocytic sarcoma.....	3	.17	0		3	.13	0	3	.79
Myxoma......	2	.11	0		2	.09	0	2	.52
Thymoma.....	2	.11	0		2	.09	0	2	.52
Rhabdomyoma	2	.11	0		2	.09	0	2	.52
Osteochondrosarcoma....	1	.055	0		1	.04	0	1	.26
Fibrochondrosarcoma....	0		1	.19	1	.04	0	1	.26
Melanoma....	1	.055	0		1	.04	0	1	.26
Lymphangioma	1	.055	0		1	.04	0	1	.26
Mesothelioma..	1	.055	0		1	.04	0	1	.26
Teratoma.....	0		1	.19	1	.04	0	1	.26
Total........	216	12.1	81	15.5	297	12.9	87	384	100.00

The relative incidence of the different varieties of neoplasia is indicated in Table 20. In addition to the numbers of different types of neoplasia found in collections A, B, and C, the frequency of incidence is calculated according to the source of material. Since collection C was derived from miscellaneous sources, data on relative frequency were not available. In order to provide a larger sample from which to obtain information on incidence as related to breed, sex, age, and season, the data for collections A and B were pooled. The distribution of all chickens over six weeks of age examined in the material providing collections A and B is given in Table 21, with respect to breed, age, and season of necropsy. Comparable data on the neoplastic diseases found in collections A and B are given in Table 22.

Only a few varieties of neoplasia are represented in sufficient numbers to justify an attempt at judging their rate of incidence in birds examined for disease. These are lymphocytoma, embryonal nephroma, myelocytoma, leukosis, and fibro-

sarcoma. The rate of incidence of these tumors was essentially similar in collections A and B. Leiomyoma, epithelioblastoma, and carcinosarcoma seemed to be relatively more common in chickens from the source of collection B and may be regarded as types of neoplasia associated with advanced age (the average ages of birds in which such tumors were found were 66.5, 67.1, and 114.1 weeks, respectively, Table 22). The greater incidence of these tumors in collection B is probably due to the different proportion of old birds examined. More than twice as many birds over 12 months of age were examined from the source of collection B (237 birds) as from the source of collection A (110 birds). Embryonal nephroma appeared to be more common in birds of collection A, but the addition of one or two more cases to collection B would have raised the incidence rate to a level comparable with that of collection A.

Therefore, collections A and B were essentially similar with respect to the incidence of the commoner forms of neoplasia.

In considering all forms of neoplasia, lymphocytoma was the most common (55.5 percent of 384 tumors studied). Although none of the other types of neoplasia were of striking frequency, six other varieties (leiomyoma, embryonal nephroma, myelocytoma, leukosis, epithelioblastoma, and fibrosarcoma) accounted for 33 percent of the tumors.

Table 21.—Distribution of Chickens over Six Weeks of Age Examined for Disease, Arranged According to Age, Breed, Sex, and Quarter of Year When Necropsied.

Collections A and B of Neoplasms were obtained from these birds.

		Distribution by Breeds							Distribution by Sex			Distribution by Quarter of Year			
Age Group (Months)	Total No. Examined	Rhode Island Red	Barred Plymouth Rock	Cross Bred	White Plymouth Rock	White Leghorn	New Hampshire	Miscellaneous and Not Recorded	Female	Male	Sex not Recorded	1	2	3	4
2—3	555	285	86	103	9	9	4	59	137	102	316	94*	226	161	74*
4—6	409	272	41	49	16	10	6	15	323	54	32	14*	53*	247	95
7—9	567	413	70	47	13	7	15	2	509	44	14	103	8*	109*	347
10—12	426	303	38	19	16	14	3	33	324	72	30	247	103	25*	51*
13—15	145	127	10	2		4		2	120	17	8	2*	93	50	0
16—18	79	65	5	4	3	2			74	5	0	0	0	58	21
19—21	46	43		1	2				33	13	0	14	0	0	32
22—24	34	32				2			26	7	1	20	13	0	1*
25+	43	40	1	1				1	29	14	0	7	15	12	9
Total	2304	1580	251	226	59	48	28	112	1575	328	401	501	511	662	630

*No chickens from Collection B are represented in these groups.

Breed

Neoplasia was found in only three breeds to an extent sufficient to warrant detailed study of the data. The difficulty of dealing with small figures again presents itself. A preliminary examination of the data in Tables 21 and 22 indicated that comparisons should be made of the incidence of lymphocytoma, myelocytoma, fibrosarcoma, and leukosis. The comparison was drawn and the

TABLE 22.—SUMMARY OF DATA ON NEOPLASMS FOUND IN COLLECTIONS A AND B.

Type of Tumor	Total Number of Cases	Distribution of Neoplasms in Collections A and B																Age of Birds at Necropsy (Weeks)		
		By Breed										By Sex		By Quarter of Year at Necropsy						
		Rhode Island Red	Barred Plymouth Rock	Cross Bred	White Plymouth Rock	White Leghorn	New Hampshire	Buff Orpington	Barnevelder	Bantam	Breed not Recorded	Male	Female	1	2	3	4	Average	Minimum	Maximum
Lymphocytoma	148	103	14	22	2	2	1	1	1	1	1	5	143	42	19	39	48	34.0	8	104
Leiomyoma	32	31	1									0	32	5	9	13	5	66.5	26	107
Embryonal nephroma	14	12					1				1	6	8	1	1	5	7	32.6	11	50
Myelocytoma	17	12	5									4	13	4	3	5	5	34.6	5	56
Leukosis	17	9	4	2		1	1					2	15	2	6	3	6	51.3	20	114
Epithelioblastoma	17	13	2	1	1							1	16	4	3	3	7	67.1	12	258
Fibrosarcoma	14	7	1	3								2	12	1	5	3	5	40.0	12	79
Carcinosarcoma	7	6		1								0	7	2	1	3	1	114.1	78	220
Neurogenic sarcoma	3			2	1							0	3	0	1	1	1	22.3	14	29
Hemangioma	4	2	1								1	0	4	0	1	0	3	35.0	28	52
Fibroma	4	4										1	3	2	0	2	0	39.8	4	52
Cholangioma	3	3										0	3	0	0	1	2	37.6	20	48
Hepatoma	2	2										0	2	0	0	1	1	24.0	20	28
Histiocytic sarcoma	3	1	1	1								0	3	0	1	0	2	36.0	28	52
Myxoma	2	1	1									2	0	0	1	1	0	16.5	7	26
Thymoma	2	1		1								0	2	1	0	0	1	57.0	36	78
Rhabdomyoma	2	2										1	1	0	0	0	2	36.0	32	40
Osteochondrosarcoma	1	1										0	1	0	0	0	1	20.0		
Fibrochondrosarcoma	1	1										0	1	0	0	0	1	91.0		
Melanoma	1	1										0	1	0	0	0	1	26.0		
Lymphangioma	1			1								0	1	0	0	0	1	32.0		
Mesothelioma	1	1										0	1	1	0	0	0	36.0		
Teratoma	1	1										1	0	1	0	0	0	78.0		
Total	297	214	33	34	4	3	3	1	1	1	3	25	272	66	51	80	100			

results tend to indicate a relatively high incidence of lymphocytoma in crossbred birds, the majority of which were the progeny from mating Rhode Island Reds with Barred Plymouth Rocks (Table 23). Several factors would influence this result; for example, the age group of birds examined and the number of flocks and breeding strains represented would be of significance. When the comparison between breeds was drawn and the frequency of incidence of lymphocytoma was based upon the cases found in the age group of from 7 to 12 months, the figures obtained were 9.9 percent for Rhode Island Red, 10.4 percent for Barred Plymouth Rock, and 13.6 percent for crossbred chickens. The difference was still apparent, and became more significant when the source of material was considered. The 103 cases of lymphocytoma in Rhode Island Red chickens came from not more than 48 sources (flocks or breeding strains) or an average of 2.14 cases per source. The 22 cases of lymphocytoma in crossbred birds were obtained from not more than 10 sources averaging 2.2 cases per source. The 14 cases in Barred Plymouth Rock chickens came from not more than 8 sources or an average of approximately 1.7 birds per source. Since the cases in Barred Plymouth Rock birds came from relatively fewer sources, it seems that the figure for incidence in the breed may be slightly too high. The result at least indicates need of more data.

TABLE 23.—INCIDENCE OF NEOPLASIA WITH RESPECT TO BREED.

Data from Collections A and B.

Type of Neoplasm	Rhode Island Red		Barred Plymouth Rock		Cross Bred		All Breeds in A and B	
	Number of Cases	Percent of Group Examined (1580)	Number of Cases	Percent of Group Examined (251)	Number of Cases	Percent of Group Examined (226)	Number of Cases	Percent of Group Examined (2304)
Lymphocytoma	103	6.52	14	5.58	22	9.74	148	6.42
Myelocytoma. .	12	.76	5	1.99	0	0	17	.74
Fibrosarcoma. .	7	.44	4	1.59	3	1.33	17	.74
Leukosis.	9	.57	4	1.59	2	.89	14	.61
All neoplasms*.	214	13.55	33	13.15	34	15.0	297	12.9

*Includes all those listed in Table 22.

The results for myelocytoma, fibrosarcoma, and leukosis, indicating a lower relative incidence in Rhode Island Red chickens, are based on too few examples to be regarded as definitely significant.

Age at Necropsy

The averages together with the low and high values for age at necropsy of chickens affected with the various tumors are listed in Table 22. It may be noted that certain tumors were more apt to be found in birds of a given age group than others. For example, lymphocytoma, embryonal nephroma, and myelocytoma appear to have been more common in birds 8 to 10 months of age; fibrosarcoma in a slightly older age group; and leukosis in birds about one year of age. Leiomyoma, epithelioblastoma, and carcinosarcoma were characterized by their occurrence in older birds.

Mathews (17) stated that the myelocytoma cases studied by him were found principally in birds less than one year of age; whereas lymphocytoma was found in birds of all ages. The present data support his claim, for the oldest bird in which myelocytoma was found was aged 56 weeks. The average of one year for the age of 12 birds with spontaneous leukosis found by Feldman and Olson (8) is

substantiated by the present study. Goss (11) as well as others had previously noted the tendency for epithelial tumors to be found in birds over one year of age.

The small number of cases of other varieties of neoplasia does not permit definite conclusions on the subject of age. However, nearly all of the other types were found in birds less than one year of age.

Sex

Tumor incidence becomes quite difficult to correlate with the factor of sex for several reasons. Although approximately equal numbers of male and female chickens are obtained at the time of hatching, a variety of conditions immediately enter to cause a change of the 1:1 ratio. Some commercial hatcheries separate the chicks into male and female groups immediately upon hatching and may sell either according to demands of the buyer. Some poultrymen raise only males, which are disposed of as broilers at a comparatively early age. Others raise only females, which are held for varying periods in egg-producing flocks. Still other poultrymen raise both males and females to broiler age or to sexual maturity (4 to 6 months). The flock may then be reduced to a point where only a relatively few males are retained for breeding purposes. The ratio of males to females may vary greatly in such flocks from 1:4 to 1:10. These factors and probably others influenced the relative numbers of males and females examined in the laboratory and in turn would influence the results obtained in the survey. While a ratio of 1 male to 4.8 females may be calculated for all birds examined in the laboratory, the ratio varied markedly (from 1:1.4 to 1:14) in the different age groups (calculated from data in Table 21).

Despite these difficulties some conclusions seem warranted from examination of the data on sex in Table 22. Leiomyoma was found only in females, and epithelioblastoma was found 16 times in females and only once in a male, strongly suggesting a tendency for these diseases to occur principally in females. Both tumors were often found in female reproductive organs and the preponderance of females with these tumors was, therefore, not surprising.

Embryonal nephroma was found relatively more often in males (6 cases) than in females (8 cases). The sex ratio of 1 male to 1.3 females for this tumor may be compared to the ratio of 1:4.8 among birds examined whose ages were from 2 to 12 months (272 males and 1293 females, Table 21). Such a comparison is logical, for such tumors were found in birds of this age group (Table 22).

The sex ratios in myelocytoma, leukosis, and fibrosarcoma were not greatly different from that of all birds examined in the comparable age group.

The question of sex in relation to lymphocytoma presents a problem in analysis. Most investigators commenting on the subject have stated that lymphocytoma appears as often in males as in females when the relative number of each sex in the general poultry population is taken into account. A similar conclusion could be drawn from the present study if one considered only the entire group of 213 cases among which were 20 males and 193 females, a ratio of 1:9.7. This ratio of approximately 1:10 is perhaps not greatly dissimilar from what might be expected to exist in the population of many general poultry farms. However, the question cannot be dismissed so lightly, for among 148 cases of lymphocytoma in collections A and B only 5 males were found with the disease as compared to 143 females, a ratio of 1:29. No such disproportionate ratio existed in any of the age groups of birds examined (Table 21). This was indeed a surprising result. Although the number of males examined (328) was small, 30 cases of lymphocytoma should have been found among males if the rate of 9.1 percent incidence for females (143 cases among 1575 examined) could be applied to males. The low rate of incidence for males in collections A and B indicates the need for careful analysis. For example, the addition of cases from collection C completely changed

the sex ratio in lymphocytoma and led to an entirely different result. Collection C could not logically be included, however, for the group was drawn from sources entirely dissimilar from collections A and B. The literature contains no data with which to compare these findings save the general comment previously mentioned which has often been made, to the effect that no evidence suggests a difference between male and female in incidence of lymphocytoma. These statements are not accompanied by figures and hence provide no basis for comparison. The data from this survey suggest that the question should be examined and satisfactory information accumulated to provide a definite answer.

Seasonal Occurrence

Schneider (29) observed an increase in frequency of tumor between May and October and a decrease between November and April, which she associated with the increased ovarian function of egg laying during the spring and summer. Different authors have discussed an apparent relation between season of the year and the occurrence of leukosis in chickens (21). Other than these comments, there is little information in the literature on seasonal occurrence of spontaneous neoplasia in chickens.

The distribution according to age and quarter of year at necropsy of 2304 birds examined in the laboratory is given in Table 21. Comparable data on birds affected with tumors are given in Table 22. The year was divided into four quarters in which the first quarter included January, February, and March, the second quarter the following three months and so on to the fourth quarter which included October, November and December. Computations to determine the significance of the findings become involved with many factors.

Since the factor of age is of importance with respect to the incidence of the various types of tumors, it must be considered in attempting to determine the effect of season upon rate of incidence of tumors. The data on quarterly incidence of seven types of neoplasia together with the total number of neoplasms are given in Table 24. An attempt is made to compensate for the factor of age, by estimating the incidence of the respective types of neoplasia in only the age group in which each type of tumor was actually encountered. Since the borders of the age groups of birds examined do not exactly coincide in all instances with the oldest and youngest chicken affected with tumor, the incidence rate is not precisely accurate. The number of cases of neoplasia and number of birds examined

Table 24.—Correlation Between Quarter of Year and Incidence of Neoplasms Among the Chickens Examined.

Neoplasm	Age Group of Birds Examined (Months)	Incidence Expressed in Percent of Group Examined and Found Affected			
		First Quarter	Second Quarter	Third Quarter	Fourth Quarter
Lymphocytoma	2–25+	8.4	3.7	5.9	7.6
Leiomyoma	7–25+	1.28	3.9	5.1	1.08
Embryonal nephroma	2–12	.22	.27	.92	1.23
Myelocytoma	2–15	.87	.62	.85	.88
Leukosis	4–25+	.49	2.10	.60	1.08
Epithelioblastoma	2–25+	.80	.59	.45	1.11
Fibrosarcoma	2–21	.21	1.03	.46	.81
All neoplasms*	2–25+	13.1	10.0	12.1	15.9

*Includes all those listed in Table 22.

are too small to be regarded as a representative sample indicative of the true condition for all chickens. In view of these facts, the results are suggestive only.

The quarterly incidence for all tumors in birds examined varied from 10 to 15.9 percent, indicating little effect of season upon incidence of tumors. However, when the seven types of tumor on which usable information was available were considered, there was only one (myelocytoma) in which season seemed to have no effect. Season or quarter of year seemed to have an irregular effect on the incidence of other neoplasms. Thus the incidence of lymphocytoma was high in the first and fourth quarters, leiomyoma high in third quarter, embryonal nephroma high in the fourth quarter, leukosis high in the second quarter, epithelial tumors high in the fourth quarter, and fibrosarcoma high in the second quarter. The similarity of incidence by quarters in leukosis and fibrosarcoma is of interest, for these two neoplasms were the only ones to show comparable rates of incidence.

These findings cannot be regarded as conclusive and merely suggest the need for further information.

Distribution of Lesions

The data on all cases of neoplasia were compiled to give information on two items; namely, the frequency of involvement of organs and tissues and the varieties of neoplasia found in different organs and tissues. These data are given in Table 25. The greatest variety (nine different kinds) of tumors was found in the musculature. The liver, gonad, and skin and subcutis each were affected with eight varieties of tumor; and the kidney, peritoneum, and intestine with seven. Six kinds of tumor were found in the lung and five in the heart. Four varieties were found in the spleen, adrenal, and pancreas. Three varieties were found affecting the blood, bone marrow, oviduct and its ligament, thymus, thyroid, parathyroid, and nerve tissue. The relative frequency of involvement of organs and tissues is indicated in Table 25 where they are listed in the descending order of frequency of involvement. The large number of cases of lymphocytoma had a marked effect on this arrangement since it was the most common type of tumor.

The distribution of lesions in the collection of neoplasms provides material that may be a useful guide in diagnosis. For example, the liver was the organ most frequently affected with new growths and although eight varieties of neoplasia were found, the most common type was lymphocytoma. This suggests that a neoplastic process in the liver is quite apt to be lymphocytoma and the suggestion can be tested by further consideration of the gross characteristics of the process and involvement of other tissues and organs. A similar analysis may be made with respect to other organs or tissues found affected with neoplasia. Obviously, of course, such generalizations are subject to error; yet they provide a basis for a rational method of arriving at a tentative diagnosis of a neoplasm as discussed in the next section.

Correlation between Tentative and Final Diagnoses

In order to obtain information on the reliability of diagnoses of neoplasia based only upon macroscopic examination, a plan to test this point was followed during the collection of most of the cases included in the survey. A tentative diagnosis was given each case at the time of necropsy and this was later correlated with the final diagnosis made after histological examination.

The results of this phase of the study are given in Table 26. The principal factors utilized in making the tentative diagnosis were the situation of the tumor and the consistency, texture, color, general character, and distribution of the lesions. Such factors as age of the bird and length of illness were given minor con-

TABLE 25.—DISTRIBUTION OF LESIONS IN 384 CASES OF NEOPLASIA FOUND IN 365 CHICKENS.

Organs or Tissues Involved	Lymphocytoma	Leiomyoma	Epithelioblastoma	Embryonal nephroma	Myelocytoma	Fowl leukosis	Fibrosarcoma	Carcinosarcoma	Neurogenic sarcoma	Hemangioma	Fibroma	Histiocytic sarcoma	Myxoma	Thymoma	Rhabdomyoma	Osteochondrosarcoma	Fibrochondrosarcoma	Melanoma	Lymphangioma	Mesothelioma	Teratoma	Percentage frequency of involvement
Total Number of Cases	213	34	24	21	20	19	16	7	5	5	5	3	2	2	2	1	1	1	1	1	1	
Liver	116	1	7		16	19	2			4		1										45.5
Kidney	108			21	8	9	3			2			1									41.6
Gonad	112		10		13			4		1		1							1		1	39.2
Spleen	93				12	19				1												34.3
Peritoneum	64		6		12		6	7				2								1		26.8
Blood	45				20	19																23.0
Bone marrow	42				15*	19																20.8
Adrenal	62		1		4			1														18.6
Intestine	42		2		5	3	1				1				1							15.1
Lung	41		2		5		1			1		1										14.0
Musculature	18	1			6	1	7		1			1			2		1					10.4
Oviduct	3	34						1														10.4
Pancreas	26		5		3			3														10.1
Heart	24		1		2					1	1											7.9
Skin and Subcutis	17		1			1	1				1		1			1	1					6.6
Bursa of Fabricius	24																					6.6
Proventriculus	22																					6.0
Thymus	11				6									2								5.2
Thyroid	10		1		5																	4.4
Parathyroid	4		1		8																	3.6
Upper respiratory tract							2				2											1.1
Skull					2											1						.8
Miscellaneous							1†		1‡									1¶				.8
Nerves:																						
Anterior Mesenteric	50				4				1													15.1
Brachial	47								1													13.1
Lumbar	43								2													12.3
Ischiadic	23								2													6.8
Vagus	23																					6.3
of Remak	20																					5.5

*Examined in only 15 cases.
†Brain.
‡Dorsal root ganglia of thoracic nerve.
¶Tongue

sideration. The characteristics of some types of neoplasia overlap so that differentiation is difficult. Many tentative diagnoses based on macroscopic observations were considered questionable when made and were later found to be erroneous. Accurate identification of some cases of neoplasia from gross examination is particularly difficult when the lesions differ considerably from those characteristic for the tumor. It is pertinent to mention that no attempt at correlation of tentative and final diagnosis was made until the entire collection had been studied, thereby eliminating the possibility of the earlier experience influencing the tentative diagnoses made during the subsequent period of collection. This experience would unquestionably lead to more accurate tentative diagnoses. Several of the incorrect diagnoses appearing in the table were not actual errors in interpretation, but were the result of concomitant tumors, the lesions of which were not given sufficiently serious consideration. In other instances, neoplasms which were not suspected on macroscopic examination at the time of necropsy were detected later by microscopic examination. This suggests that unrecognized neoplasms may have been present in some birds considered negative for

TABLE 26.—CORRELATION OF TENTATIVE AND FINAL DIAGNOSES IN 301 CASES OF NEOPLASTIC AND NON-NEOPLASTIC DISEASE FOUND IN 284 CHICKENS.

Final Diagnoses	Tentative Diagnoses: Lymphocytoma	Leiomyoma	Embryonal nephroma	Myelocytoma	Leukosis	Epithelio-blastoma	Fibrosarcoma	Neurogenic sarcoma	Hemangioma	Fibroma	Cholangioma	Hepatoma	Histiocytic sarcoma	Myxoma	Thymoma	Chondro-blastoma	Melanoma	Mesothelioma	Teratoma	Endothelioma	Granuloma	Cirrhosis	Fowl paralysis	Cyst	No diagnosis	Total of Final Diagnoses	Percentage Accuracy
Lymphocytoma	108	1		3	1	5	11	6			1	2	3		1			1			2		6		2	153	71
Leiomyoma		20				1			2									1			1					25	80
Embryonal nephroma			9				3																	1		13	69
Myelocytoma	3			8			1														1				2	15	53
Leukosis	3				11																	1			1	16	69
Epithelioblastoma	1					7			2				1							1				1	2	15	47
Fibrosarcoma							5			1	1		1			1					1				1	11	45
Carcinosarcoma						2												1								3	0
Neurogenic sarcoma								3																		3	100
Hemangioma	1				1				1																1	4	25
Fibroma	1						2									1										4	0
Cholangioma				1								1									1					3	0
Hepatoma												2														2	100
Histiocytic sarcoma	2						1																			3	0
Myxoma														2												2	100
Thymoma															2											2	100
Rhabdomyoma							2																			2	0
Osteochondrosarcoma																1										1	100
Melanoma																	1									1	100
Lymphangioma						1																				1	0
Mesothelioma																		1								1	100
Teratoma																			1							1	100
Non-neoplastic diseases*	8			5	3				1		1	2														20	0
Total Tentative Diagnoses	127	21	9	17	16	16	25	9	6	1	3	7	5	2	3	3	1	4	1	1	6	1	6	2	9	301	
Percentage Accuracy	85	95	100	47	69	44	20	33	17	0	0	29	0	100	67	33	100	25	100	0	0	0	0	0			

*Includes hepatitis, cirrhosis, granuloma, nephritis, cyst, and lymphoid hyperplasia which were mistaken for neoplastic disease on gross examination.

tumors. The number of cases of neoplastic disease which passed unobserved in the present survey cannot be estimated, yet some may have occurred. Careful consideration was given to all material at the time of necropsy before it was rejected as non-neoplastic. Many suspicious cases which later proved to be other than neoplastic in character were included for histological study. Differentiation between neoplastic and non-neoplastic conditions from macroscopic examination is usually considered fairly simple. It will be noted, however, that some errors were made in such differentiation in the present survey. Bacteriological and other examinations to determine the etiology of lesions will sometimes assist in differentiating between neoplastic and non-neoplastic conditions. However, since neoplasia and granuloma may exist simultaneously in the same bird, the diagnosis of a granulomatous process does not necessarily eliminate the existence of neoplasia in a given chicken.

The degree of accuracy of tentative diagnoses as shown in Table 26 represents two correlations calculated from the data. One correlation indicates the percentage accuracy of recognition of cases actually found to be the respective types of neoplasia. For example, 108 of 153 lymphocytomas were recognized on macroscopic examination as lymphocytoma (71 percent). The other correlation indicates percentage accuracy of all tentative diagnoses. For example, 127 tentative diagnoses of lymphocytoma were made and 108 cases proved to be lymphocytoma (85 percent). Correct tentative diagnoses were made in 182 of 301 instances of neoplastic and non-neoplastic diseases thus indicating a degree of accuracy of 60.4 percent. The degree of accuracy varied considerably. To illustrate, leiomyoma and embryonal nephroma were usually correctly recognized, whereas epithelioblastoma and fibrosarcoma were not.

A rather high degree of accuracy was obtained in the tentative diagnosis of lymphocytoma, since 108 of the 153 cases of lymphocytoma were correctly identified. The 45 which were not correctly identified were confused with a wide variety of conditions (Table 26). The differentiation between lymphocytoma and myelocytoma on macroscopic features alone should not as a rule be difficult (Plates II and IV). In an occasional lymphocytoma with an extremely diffuse character, relatively soft texture, and unusually white color, the absence of periosteal involvement should be of assistance in differentiation. When this characteristic of periosteal involvement is not present in cases of myelocytoma, differentiation may be difficult. Although only eight of the fifteen myelocytomas (53 percent) were recognized at the time of necropsy and eight of the seventeen tentative diagnoses of myelocytoma proved correct (47 percent), this type of tumor usually has distinguishing characteristics and should be more readily identified on gross examination. Eleven of the sixteen cases of leukosis were identified (69 percent) and the same proportion of tentative diagnoses of leukosis proved to be correct. Leukosis may at times be difficult to differentiate from lymphocytoma if blood smears are not examined. The three cases of leukosis which were called lymphocytoma were quite similar. A brief description indicates the lack of differential features in these cases. In each the moderately enlarged liver was reddish-brown in color with a diffuse gray stippling, the bone marrow grayish red, the spleen slightly or moderately enlarged, and the kidneys uniformly swollen. Such a description might obtain for either disease and the correct differential diagnosis of such cases may be extremely difficult without the aid of histological examination. Leukosis was confused also with granulomatous and inflammatory liver changes in a limited number of cases. Texture and consistency are important factors in the differentiation between lymphocytoma, epithelioblastoma, and fibrosarcoma, particularly in cases involving the abdominal organs such as the peritoneum, pancreas, and ovary. Epithelioblastoma and fibroblastoma are usually very firm and may be particularly difficult to differentiate from each

other. Histiocytic sarcomas and carcinosarcomas may also be included in this group which may require microscopic examination for accurate identification.

A nodular type of tumor found widespread over the peritoneum, usually involving abdominal organs and associated with considerable ascites, proved to be either carcinosarcoma, fibrosarcoma, or carcinoma (Plate VIII, Figure 1; Plate XII, Figure 1). Satisfactory criteria for distinguishing these tumors on macroscopic examination could not be established. Fibrosarcoma proved particularly difficult to identify accurately on macroscopic examination. Only five of the twenty-five diagnoses proved correct (20 percent), and five of the eleven fibrosarcomas were recognized on macroscopic examination (45 percent). Of the inaccurate tentative diagnoses, eleven proved to be lymphocytoma and the remainder were principally other neoplasms of connective tissue origin.

Leiomyomas involving the ventral ligament of the oviduct usually were properly recognized (Plate XII, Figure 2). Leiomyomas occurring in the wall of the oviduct, in the intestine, and in other locations might be more difficult to identify from macroscopic examination.

The gross character of embryonal nephroma is quite variable and might lead to incorrect interpretation (Plate X, Figures 1 and 2). However, encapsulated tumors arising from the kidney or its vicinity, even though the base be narrow or the attachment rather loose, can be reasonably correctly identified as embryonal nephroma, particularly in the absence of lesions in other organs. No tentative diagnosis of embryonal nephroma proved to be incorrect. Three of the four embryonal nephromas which were not recognized as such were classed as fibrosarcoma on gross examination and one was considered to represent a cystic kidney.

The incorrect tentative designation of neurogenic sarcoma in seven cases of lymphocytoma was based largely on location of the lesions. The neurogenic sarcomas were in general of a more glistening white color and of firmer consistency. Those neurogenic sarcomas which are encapsulated should be more readily recognized than those which invade and infiltrate adjacent tissues (Plate I, Figures 1 and 3).

To differentiate neoplasia from granulomatous and inflammatory reactions may be difficult, particularly when necrosis occurs in the substance of a tumor. Marked post-mortem changes may lead to confusion. Likewise the concomitant existence of both a granulomatous process and neoplastic disease in the same bird may give trouble in correctly identifying a tumor. Inflammatory and neoplastic processes in the proventriculus may be particularly difficult to differentiate. Cholangioma, cholangitis, and cirrhotic liver changes may have many points of resemblance. The differentiation between lymphocytoma in the kidney and chronic nephritis may occasionally be difficult, but in general the kidney in chronic nephritis has a firmer texture.

The identification of tumors is often considered a difficult problem. In many laboratories engaged in the diagnosis of poultry diseases, histological examinations are not made of all neoplasms, and instances of neoplastic disease encountered in such laboratories are apt to be relegated to the doubtful category of tumors. It would seem desirable to improve this situation and designate the type of tumors observed as accurately as possible. Considerable accuracy and confidence in identification of tumors upon macroscopic examination can be attained by application of knowledge gained from a correlation of a series of diagnoses tentatively based on macroscopic and checked by microscopic examination. Such a study would not be impractical for most diagnostic laboratories. After completion of such a series, occasional check examinations could be made to maintain accuracy and confidence. Histological examination should always be resorted to in doubtful cases.

Although it is not to be inferred that the identification of tumors from macroscopic examination only is a recommended procedure, it must be recognized that routine histological examination may not be practical in laboratories established only for the examination of poultry specimens. Even though there may be considerable error in such tentative diagnoses, the laboratory records would, however, be more understandable and usable if such identification were available.

Perhaps the accurate diagnosis of the less common neoplasms is not of economic importance since they are observed only infrequently. At the present time, heredity in relation to neoplastic disease is receiving much emphasis. Many flock owners are selecting families for their breeding flocks on the basis of tumor incidence. If heredity is of importance in certain types of tumors and not in others, there may be unnecessary elimination of families unless the types of tumors are identified.

Concomitant Tumors

Two different types of neoplasia were found in the same chicken in nineteen instances. These have been mentioned in the sections dealing with the various types of neoplasia, and only a brief comment will be made here to summarize the findings.

Lymphocytoma was found to exist with embryonal nephroma in four cases, with neurogenic sarcoma in one case, and with leukosis in one case. Leukosis was associated twice with myelocytoma and once with fibrosarcoma. Myelocytoma and embryonal nephroma were both found in one bird. Both histiocytic sarcoma and hemangioma occurred in one chicken. The diagnosis of both leiomyoma and carcinosarcoma was made in four cases, and leiomyoma of the oviduct was found with epithelioblastoma of the ovary twice. Adenoma of the thyroid and melanoma of the tongue were coexisting tumors in one case, and in another case an adenoma of the pancreas was found in a bird which also had a large fibrosarcoma in its pelvic cavity.

Such concomitant neoplasia excites interest in the possibility of an etiological relationship. Only two combinations of concomitant neoplasia were found in a sufficient number of cases to attract attention. The explanation of the combination of lymphocytoma and embryonal nephroma, found four times, on an etiological basis does not seem logical. Embryonal nephroma is usually regarded as a neoplasm which results from a derangement of tissue during embryonic life; whereas the hypothetical agent (if such exists) of lymphocytoma may be assumed to exert its action in post-embryonic life. Thus the two diseases seem to be initiated at different periods of life and it appears unlikely that an etiological relationship exists.

The association of leiomyoma with tumors of epithelial origin, especially carcinosarcoma, is discussed in the section dealing with carcinosarcoma. Both epithelioblastoma and leiomyoma were more common in birds of the older age group and this would tend to increase the possibility of both occurring in the same chicken. The number of cases in the study is small and for the present the association of leiomyoma and epithelioblastoma should probably be regarded as merely incidental.

SUMMARY AND CONCLUSIONS

A collection of 384 cases of spontaneous neoplastic disease found in 365 chickens has been studied. Since most of the material was submitted to the diagnostic laboratory of Massachusetts State College, some information was gained on the relative incidence of neoplastic disease among birds submitted for necropsy. An incidence rate of 12.9 percent for neoplastic disease was found in 2304 chickens over six weeks of age that were examined in the laboratory.

Twenty-five different kinds of neoplasms were found. Lymphocytoma was the most common and accounted for 55.5 percent of the 384 cases. Six other varieties (leiomyoma, embryonal nephroma, myelocytoma, leukosis, epithelioblastoma, and fibrosarcoma) accounted for 33 percent of the tumors. Each of the varieties of neoplasia is described and the data compiled for study. The incidence of neoplasia was studied in relation to various factors, such as age at necropsy, sex, seasonal occurrence, and breed. Each of these appeared to be of significance in one or more types of tumor.

In some of the cases tentative diagnoses, based on macroscopic examination only, were later correlated with the final diagnoses in an effort to determine the accuracy of such tentative diagnoses. The results, together with sources of error, are discussed.

The data on lymphocytoma provided a basis for a possible explanation of the different forms of this disease. Other neoplasms on which new information of significance was found were leiomyoma, neurogenic sarcoma, and carcinosarcoma.

It may be concluded that spontaneous neoplastic disease in the chicken is relatively common and that, although lymphocytoma is the most common and causes the most loss, the other kinds are responsible for a significant share of the loss due to neoplasia.

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AGRICULTURAL EXPERIMENT STATION

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Blooming Dates of Some Selected Hardy Perennials

By Harold S. Tiffany

A flower lover's ambition is to have some blooms available in the garden at all times during the growing season. This bulletin should be of service in the selection of perennials for that purpose.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

BLOOMING DATES OF SOME SELECTED HARDY PERENNIALS

By Harold S. Tiffany
Assistant Research Professor of Nurseryculture

Introduction

A study of the garden value and hardiness of herbaceous perennial material was begun at the Waltham Field Station of the Massachusetts Agricultural Experiment Station in 1931. Evaluation of the material continued until 1936 when a recording of the time and duration of the flowering, heights, and color of some 2,000 perennials was begun. These records were continued through 1941 for the purpose of securing sufficient data from which to determine the *average* time and duration of bloom during these five years. From this study are drawn the conclusions which follow.

Although several very excellent works on this subject have been written, it appears that the broad scope of material included has in itself tended to confuse and baffle the average gardener. Therefore, a limited list of superior selections of tried and proved material has been drawn up for the purpose of a more useful and workable reference.

The question of what plants are most desirable has as many answers as there are differing and varying landscape developments in which certain plants are more suitable than others. Included are such hardy species and varietal forms as are generally adapted to perennial borders, formal and informal gardens, and a few which are at home in meadow or wild garden plantings. Most of these are readily obtainable in the trade. All the plants are of simple culture.

It must be kept in mind that blooming dates, particularly of early flowering plants, are very irregular because of climatic conditions bringing either an early or a late spring. While, in some cases, early flowering plants have differed in their flowering period in certain years by as much as three weeks, this variability gradually decreases as the season progresses and little variation is found after June in fairly normal years. For Cape Cod, average bloom dates would be advanced approximately one week, and for the area north of Boston and the Berkshires retarded a like period. The lateness of flowering of the early bulbs as given in the lists is due to a mulch covering over winter. Neither very early bud breaking nor late sparse continuation of bloom has been included, the aim being to give the period of bloom when the flowering is at its height for best garden value.

It has been the policy to test the plants under *average* conditions in order to determine which would best survive with ordinary care rather than to work for maximum horticultural excellence. While this attitude has been adopted more because of economic necessity than for other reasons, the plants have thus been given a fairly severe test. The gardens have the benefit of full sun and are not closely protected by hedges or windbreaks.

The plants are listed in three sections in the order of their appearance of bloom from day to day: Spring (April-May-June); Summer (July-August); and Fall (September-October).

Scientific names are given in italics, with stress on the proper syllable of the Latin name, while common and varietal names[1] are given in boldface. Synonyms are indicated on the plates and in the index by parentheses which immediately follow a genus, species, or varietal name. Such synonyms are given either to aid in identification in instances when the accepted name has recently been changed, or because the plant may appear in nursery catalog lists under either name. The words "Horticultural variety" have been shortened to "Hort. var."

Color designations have been made as simple as possible. In such descriptions as, for example, violet-**blue**, the second word (in boldface) represents the dominant color of the flower, while the modifying color tone preceding aids in giving a more exact description. All blooms have been checked against "Color Standards and Color Nomenclature" by Robert Ridgway.

Appreciative acknowledgement is made to Harlan P. Kelsey for the privilege of checking nomenclature with the proof sheets of the 1942 edition of "Standardized Plant Names" and for his constructive criticism; to Winthrop Thurlow for suggestions and assistance in the selection of the peonies for the bulletin; to Howard and Clifford Corliss for checking the lists of garden phlox; and to other members of the Massachusetts Nurserymen's Association who have cooperated so generously.

Suggestions for a Succession of Perennial Bloom from April to October

For a continuation of bloom throughout the season, it is essential first to know fairly definitely when each plant can be depended upon for its flowering period. Secondly, for an effective floral display each month, it is obviously necessary that an equal garden area be reserved for the plants which are to furnish the bloom for each of the months of the season.

Perennials have probably been selected more for their individual appeal than for a strict continuation of bloom from spring to fall. Were the average garden to be checked over from this point of view, it is probable that the area given over to June flowering plants would prove greater than that given to those blooming in May, July, August, September, and October combined. This condition can be bettered by selecting a few basic plants for flowering each month. After this has been done, elimination of the only partially successful, and restriction of the area occupied by June bloomers, will provide space for the inclusion of material needed for other periods. Best results will be gained by the use of such material as will provide bloom for intervals of every two weeks.

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[1]The 1942 edition of Standardized Plant Names was used as reference for stress and approved common and scientific names. Varietal names of irises are given in the lists as in the "Alphabetical Iris Check List" (1939 edition) of the American Iris Society.

Notes on Some of the Perennials Included

Aster

Over 400 species and varieties of this genus have been studied and evaluated at Waltham since 1933 by Professor Ray M. Koon. All available material from North America and Europe has been collected and grown. From this study 50 asters have shown outstanding garden value and hardiness, and of these, 14 have been selected as the finest.

While the majority of asters are fall blooming, the variety Star of Eisenach blooms in June and it is a superior aster for rock garden and border uses. Particular mention might well be made of Mt. Everest, the best of the whites; Harringtons Pink and Survivor as the only true rose-pinks; Violetta which supersedes all others in blue tones; Burbanks Charming and Campbells Pink, which, withstanding frosts, offer color in the garden later in the season than any others

The height of asters differs considerably with varied soils and available moisture, while their blooming dates are influenced by the age of the plants and climatic factors.

Chrysanthemum

The variable climatic conditions of Massachusetts winters are particularly trying to fall-blooming chrysanthemums. Generally, it would be well to locate them in as protected exposures as possible, covering them over winter with cranberry clippings, salt marsh hay, or similar material. Excellent early-blooming types are rapidly being produced, assuring both an earlier and a longer blooming season. In this bulletin the earliest bloomers are listed.

Confusion is general as to the common name of *Chrysanthemum maximum*. The approved name is PYRENEES CHRYSANTHEMUM and not Shasta Daisy which designates a particular variety or clonal form of this species.

Iris

The American Iris Society divides the irises herein listed into two main divisions: (1) BEARDED and (2) BEARDLESS Irises.

The BEARDED group (incorrectly known as German Iris) is distinguished by the beard on the lower petal or fall and by the broad rhizome growing at the surface of the soil. Forms of this group are designated in the lists as TB (Tall Bearded, 30 inches or over); IB (Intermediate Bearded, 18 to 28 inches, inclusive); and DB (Dwarf Bearded, up to 17 inches, inclusive).

The BEARDLESS Irises included in the lists are SIBERIAN (*sibirica*) blooming shortly after the bearded group, and the JAPANESE (*kaempferi*) blooming in early July. Characteristics of this group include: the lack of the beard on the lower petal or fall; narrower, more grasslike leaves; and a fibrous root system.

The tall bearded irises herein listed do not include a representation of the entire color range which is now included in the test gardens, for in 1940–41, through the efforts of Mr. Harold T. Bent, the iris plantings were thoroughly revised, in co-

operation with the New England Division of the American Iris Society. Further reports will include these newer varieties, which are entirely within the price range of the average purse.

Peony

All commonly cultivated herbaceous peonies come from the species *Paeonia albiflora sinensis*. They might be divided roughly into three groups: (1) the SINGLE type, with one or two rows of guard petals and numerous pollen-covered stamens; (2) the DOUBLE type, which may be fully double without stamens or semi-double with stamens intermingled with the petals (there are many gradations from semi-double to the fully double in which the seed pods or ovaries also have become petals); and (3) the JAPANESE type, which appears quite like the single type in the singleness of the guard petals but differs in the effect produced by the stamens, which have been bred into quite narrow, thickened petals or petaloids almost devoid of pollen. This characteristic results in a cushion-like effect of multiplied stamens which often take on the color of the guard petals, giving the entire flower a single tone of color. They have become the favorite of the Japanese, who have developed them exclusively, and it is for this reason that the group is known as the Japanese type. Their flowers, having less weight than the double types, are not so likely to remain prostrate after storms; the blooms last well when cut and are particularly desirable for their decorative effect.

Following the varietal name of the various peonies in the lists is the numerical rating given each by the American Peony Society. The highest possible rating is 10.

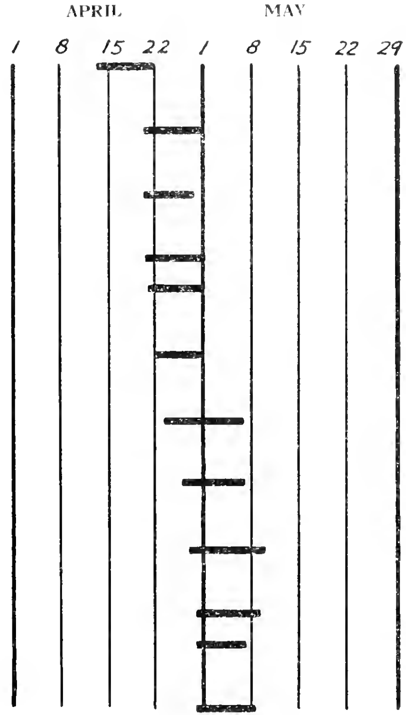
Summer Phlox

Phlox, which contributes more generously to July–August garden color than any other genus, is well represented here. Time of bloom (early, mid-season, or late), dwarfness and tallness, good branching habit, size of floret, and color have all been considered. With the exception of a few newer forms of particular promise, those listed represent the best of the standard phlox which are generally available in Massachusetts.

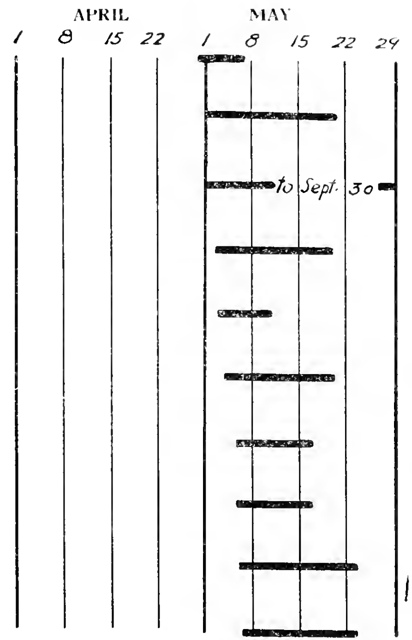
Tulip

Only the best of the tulip species for use in the rock garden have been included in the lists. While these are not now generally available on account of international conditions, they have been included because of the early, crisp brilliance with which their vivid colors open the season. For a succession of vivid vermilion-scarlet, as few as three bulbs each of *fosteriana*, *praestans*, *eichleri*, *wilsoniana* and *greigi* will create a surprising effect. Plant them near blue-flowering plants such as Grape Hyacinth and delight in the sparkle their color brings to the blue masses.

SPRING SECTION (APRIL–MAY–JUNE)

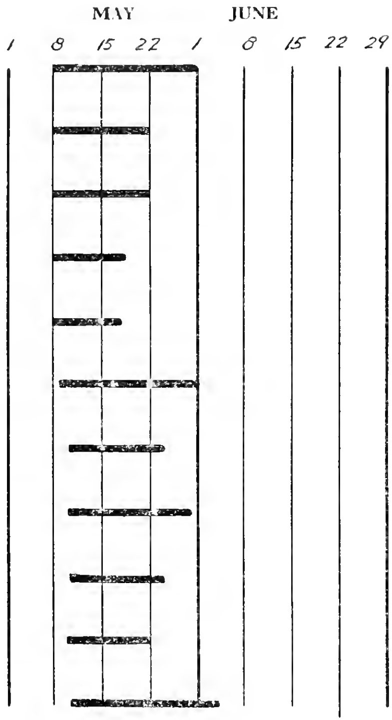


	COLOR	HEIGHT INCHES
Cro'cus susia'nus* **Clothofgold Crocus	Orange-**yellow**	3
Chionodox'a lucil'iae*, **Gloryofthesnow Hort. var. **Rose** (*rosea*)	**Pink**	8
Eran'this hyema'lis cilic'ica* **Cilician Winteraconite	**Yellow**	4
* *Hyacin'thus azu'reus* (*Muscari azureus*)	Light **blue**	8
Scil'la sibir'ica*, **Siberian Squill Hort. var. **Azurea**	**Blue**	6
Cro'cus sie'beri* **Sieber Crocus	**Lilac**	5
Scil'la sibir'ica* **Siberian Squill	Deep **blue**	6
Puschkin'ia scilloi'des libanot'ica* **Lebanon Puschkinia	**Blue**	8
Scil'la sibir'ica*, **Siberian Squill Hort. var. **Spring Beauty**	Pale lilac-**blue**	7
* *Narcis'sus mi'nor*	**Yellow**	5
Tu'lipa kaufmannia'na* **Waterlily Tulip	Light **yellow,** tinged carmine	11
Chionodox'a lucil'iae* **Gloryofthesnow	Bright **blue,** white center	5

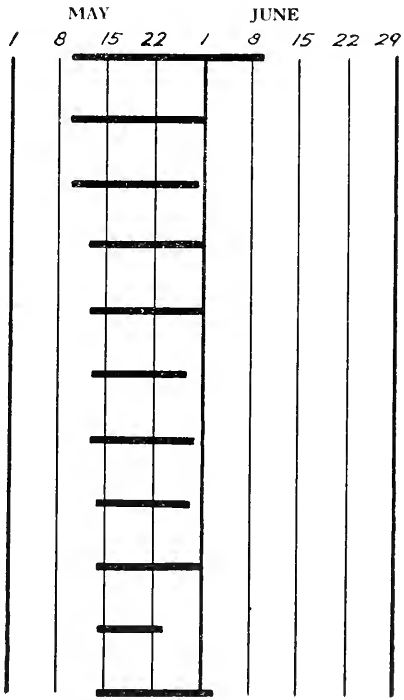


**Tu'lipa kaufmannia'na*, Waterlily Tulip Hort. var. Primrose	Yellow	14
Merten'sia virgin'ica Virginia Bluebells	Blue	24
†**Vio'la cornu'ta*, Horned Violet Hort. var. Fragrance	Blue-violet	6
**Dra'ba sibir'ica (repens)* Siberian Draba	Yellow	6
**Tu'lipa prae'stans* Leatherbulb Tulip	Red	16
**Musca'ri botryoi'des al'bum* White Common Grapehyacinth	White	10
**Tu'lipa fosteria'na* Foster Tulip	Brilliant vermilion	16
**Tu'lipa fosteria'na*, Foster Tulip Hort. var. Red Emperor	Brilliant vermilion	16
**Musca'ri botryoi'des*, Common Grapehyacinth Hort. var. Heavenly Blue	Blue	9
**Tu'lipa suave'olens*, Ducvanthol Tulip Hort. var. White	White	16

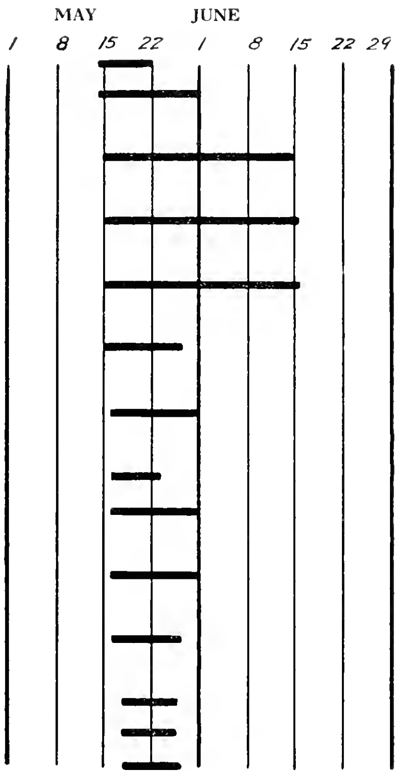
*Suitable for Rock Garden.
†Has been grown in test gardens one year only but merits inclusion.



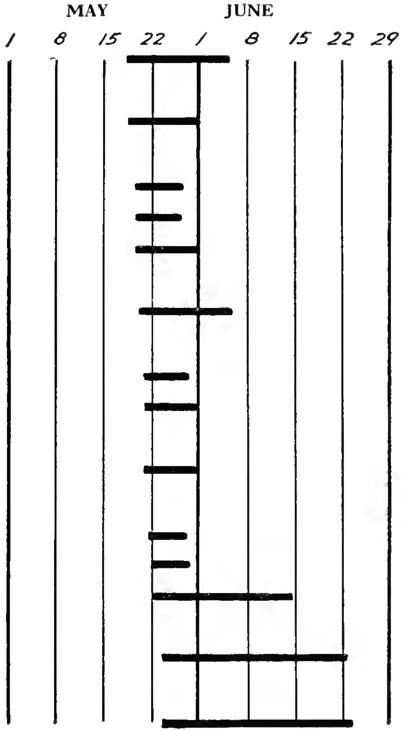
	COLOR	HEIGHT INCHES
Ar'abis albi'da floreple'no* **Double Wall Rockcress	White	10
Ar'abis alpi'na*, **Alpine Rockcress Hort. var. **Rose** (*rosea*)	Pale **pink**	5
Tril'lium grandiflo'rum* **Snow Trillium	**White**	12
Tu'lipa dasyste'mon* **Kuenlun Tulip	**Yellow,** several blooms each stem	6
Tu'lipa eich'leri* **Eichler Tulip	Brilliant crimson-**scarlet**	12
Doro'nicum caucas'icum, **Caucasian Leopardbane** Hort var. **Mme. Mason**	Lemon-**yellow**	19
Alys'sum saxat'ile*, **Goldentuft Alyssum Hort var. **Dwarf** (*compactum*)	Lemon-**yellow**	17
Ar'abis mol'lis* **Downy Rockcress	**White**	11
Aubrie'ta deltoi'dea*, **Common Aubrieta Hort. var. **Henderson** (*hendersoni*)	Amethyst-**violet**	4
Berge'nia cordifo'lia* (*Saxifraga cordifolia*) **Heartleaf Bergenia	**Rose**	20
Brun'nera macrophyl'la* (*Anchusa myosotidiflora*) **Heartleaf Brunnera (Siberian Bugloss)	Light **blue**	12



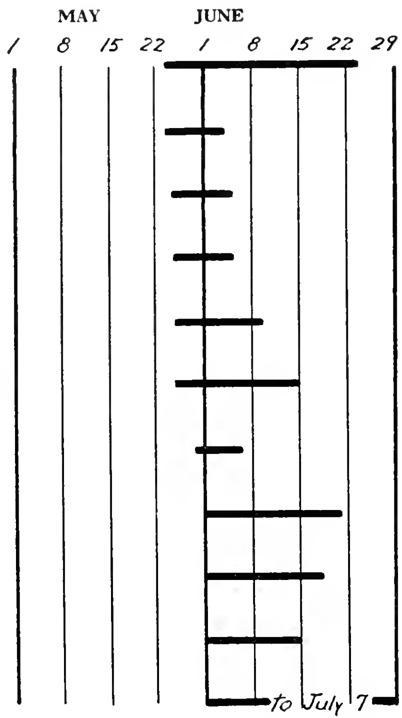
Dicen'tra spectab'ilis **Common Bleedingheart**	Deep **pink**	36
******Phlox' lilaci'na* **Lilac Phlox**	Blue-**lilac**	6
Tiarel'la cordifo'lia* **Allegany Foamflower	**Ivory**	11
Anem'one pulsatil'la*, **European Pasqueflower Hort var. **Red** (*rubra*)	Deep **red**	10
Doro'nicum clu'si **Downy Leopardbane**	Lemon-**yellow**	26
Phlox' lilaci'na, **Lilac Phlox** Hort. var. **Bluehill**	Violet-**gray**	7
Alys'sum saxat'ile*, **Goldentuft Alyssum Hort. var. **Silverqueen**	Pale **yellow**	12
Phlox' subula'ta*, **Moss Phlox Hort. var. **Atropurpurea**	Rose-**purple**	6
Phlox' subula'ta*, **Moss Phlox Hort. var. **Heather**	**Lilac**	6
Tu'lipa sylves'tris* **Florentine Tulip	Bright **yellow**	14
Phlox' frondo'sa* Hort. var. **Vivid	True **pink**, dotted red eye	4



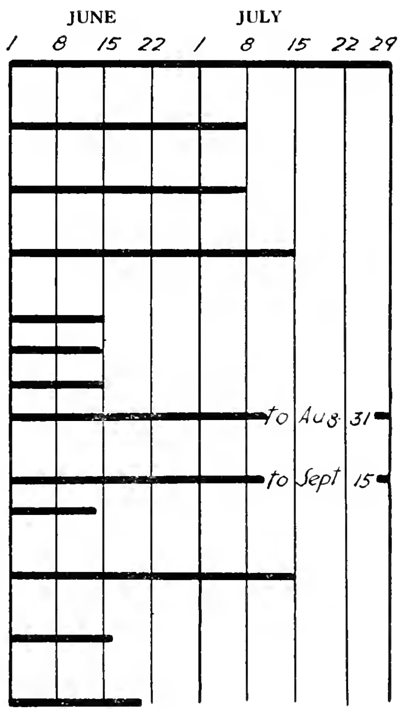
	COLOR	HEIGHT INCHES
I'ris* (DB) **Marocain	Deep violet-**purple**	10
Phlox' subula'ta*, **Moss Phlox Hort. var. **Samson**	Bright deep **rose**	7
Aethione'ma warleyen'se* **Warley Stonecress	**Pink**	5
Dicen'tra exim'ia* **Fringed Bleedingheart	**Rose**	12
Phlox' niva'lis*, **Trailing Phlox Hort. var. **Camla**	**Pink**	9
Tu'lipa greig'i* **Greig Tulip	Vivid orange-**scarlet**	12
Actine'a herba'cea* **Ontario Actinea	**Yellow**	9
I'ris* (DB) **Orange Queen	Light orange-**yellow**	10
Phlox' subula'ta*, **Moss Phlox Hort. var. **Maysnow** (Maischnee)	**White**, yellow stamens	5
Phlox' subula'ta*, **Moss Phlox Hort. var. **Schneewittchen**	Pure **white** (miniature florets)	5
Tu'lipa wilsonia'na* **Wilson Tulip	Vermilion-**red**	6
I'ris* (DB) **Ditton Purple	**Violet**	11
I'ris* (DB) **Reflection	Light gray-**blue**	12
I'ris* (DB) **Tony	Violet-**purple**	10



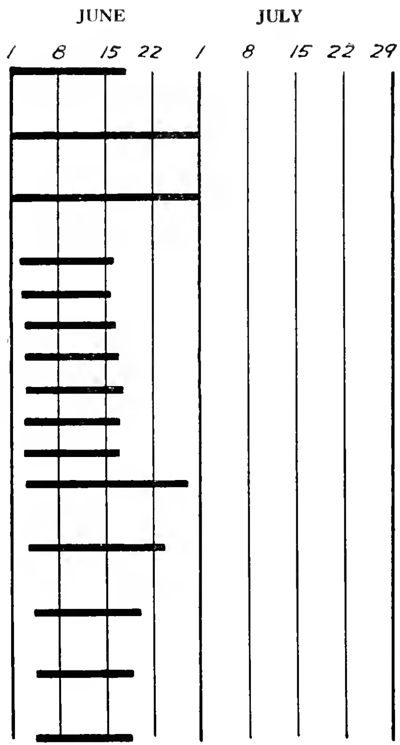
Phlox' subula'ta*, **Moss Phlox Hort. var. **Rhonsdorf Beauty** (Rhonsdorfer Schone)	Light **pink**	6
Trol'lius europae'us, **Common Globeflower** Hort. var. **Eleanor**	**Yellow**	18
I'ris* (DB) **Black Midget	Violet-**purple**	11
I'ris* (DB) **Canary Bird	Pale **yellow**	9
Tu'lipa clusia'na* **Clusius Tulip	**White to yellow**	14
Aju'ga geneven'sis*, **Geneva Bugle Hort. var. **Rose** (*rosea*)	Light **pink**	7
I'ris* (DB) **Huron Imp	Dark violet-**purple**	8
Tu'lipa linifo'lia* **Slimleaf Tulip	Brilliant **scarlet**	12
Vio'la odora'ta*, **Sweet Violet Hort. var. **Rosina**	**Rose**	5
I'ris* (IB) **Aphylla Osiris	Blue-**violet**	12
I'ris* (DB) **Mogador	Chartreuse-**yellow**	13
Nep'eta mussi'ni* **Persian Nepeta	Blue-**violet**	11
Ge'um chiloen'se, **Chile Avens** Hort. var. **Fireopal**	Red-**orange**	18
Ge'um chiloen'se, **Chile Avens** Hort var. **Princess Juliana**	Light-**orange**	24



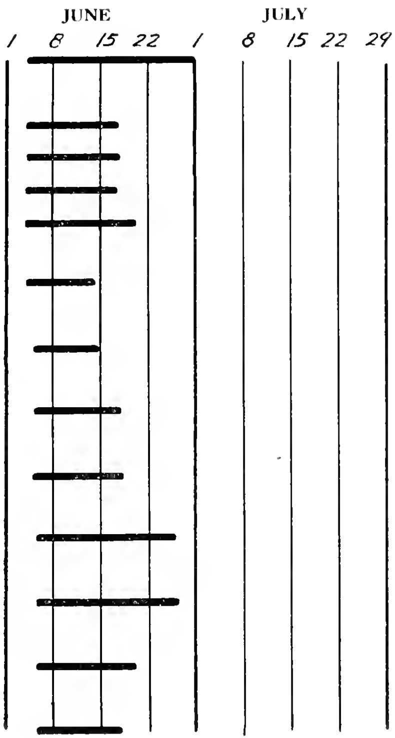
Plant	COLOR	HEIGHT INCHES
†*Ge'um chiloen'se*, **Chile Avens** Hort. var. **Red Wings**	Red-**scarlet**	30
Tu'lipa marjolet'ti* **Marjolett Tulip	Pale **yellow**, exterior of petals purple-margined	16
Scil'la nonscrip'ta*, **Common Blue Squill Hort. var. **Caerulea**	Light wisteria-**violet**	18
Aquile'gia flabella'ta na'na al'ba* **Double Whitefan Columbine	**White**	13
Camas'sia leicht'lini **Leichtlin Camas**	Blue-**violet**	42
Lupi'nus polyphyl'lus, **Washington Lupine** Hort. var. **Blush** (*roseus*)	Pale **pink**	21
Tu'lipa pa'tens* **Persian Tulip	**White to yellow**	8
Centau'rea monta'na **Mountainbluet**	Violet-**blue**	24
Gypsoph'ila re'pens* **Creeping Gypsophila	**White**	6
Heu'chera sanguin'ea, **Coralbells** Hort var. **Blooms**	**Pink,** rose tipped	34
Heu'chera sanguin'ea, **Coralbells** Hort. var. **Cathedral Bells**	Bright rose-**red,** white base	30



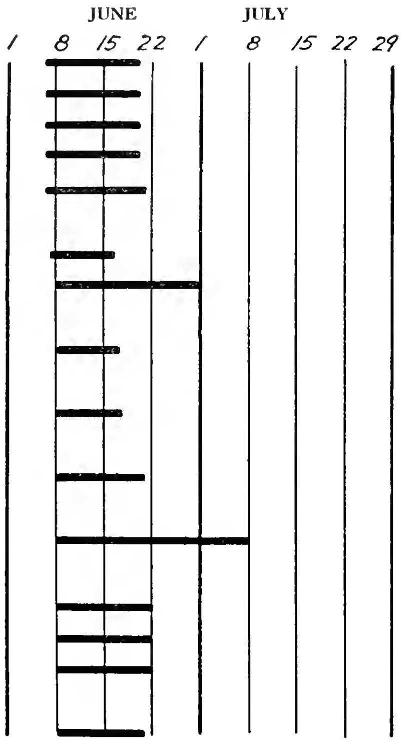
Heu'chera sanguin'ea, **Coralbells** Hort. var. **Garnet**	Light **Pink**	21
Heu'chera sanguin'ea, **Coralbells** Hort var. **Jubilee**	Pale **pink**	26
Heu'chera sanguin'ea, **Coralbells** Hort. var. **Pluie de Feu**	**Red**	25
† *Heu'chera sanguin'ea*, **Coralbells** Hort. var. **Snowflake**	Pure **white**	29
I'ris (TB) **Coronation**	**Yellow** self	36
I'ris (TB) **Dolly Madison**	**Blue** toned blend	36
I'ris (TB) **M. A. Porter**	**Purple** bicolor	34
* *Lo'tus cornicula'tus* **Birdsfoot Deervetch**	**Yellow** tinged red	15
* *Lo'tus siliquo'sus*	Lemon-**yellow**	12
Lupi'nus polyphyl'lus **Washington Lupine**	Blue-**violet**	30
Papa'ver schinzia'num **Schinz Poppy**	Light **orange**	26
* *Phlox' ova'ta* **Mountain Phlox**	Deep rose-**pink**	15
* *Potentil'la tridenta'ta* **Wineleaf Cinquefoil**	**White**	8



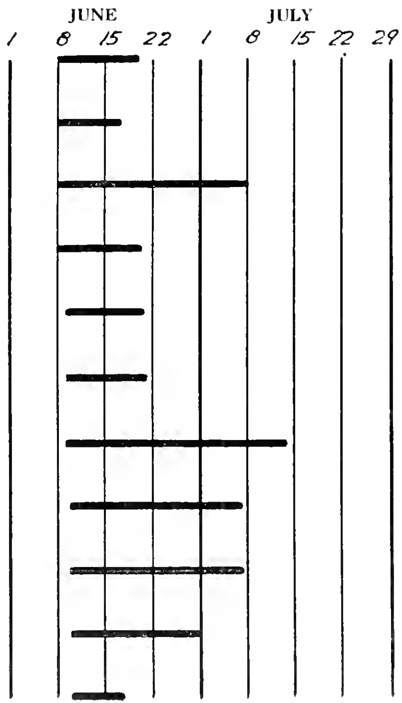
	COLOR	HEIGHT INCHES
Sapona'ria ocymoi'des* **Rock Soapwort	Clear pale **pink**	6
Tradescan'tia virginia'na, **Virginia Spiderwort** Hort. var. **James C. Weguelin**	Pale blue-**violet**	12
Tradescan'tia virginia'na, **Virginia Spiderwort** Hort. var. **Pink** (*rosea*)	Rose-**purple**	24
I'ris (TB) **Dauntless**	Purple-**red**	40
I'ris (TB) **Lady Gage**	**White**	30
I'ris (TB) **Ambrosia**	Pink-**white** self	36
I'ris (TB) **Gloriole**	Frosty light **blue** self	38
I'ris (TB) **Indian Chief**	Purple-**red** self	38
I'ris (TB) **Mount Royal**	**Blue** bicolor	36
I'ris (TB) **Princess Beatrice**	Light **blue** self	44
Saturei'a alpi'na* **Alpine Savory	**Violet**	6
Thalic'trum aquilegifo'lium, **Columbine Meadowrue** Hort. var. **White** (*album*)	**White**	36
Aquile'gia*, **Columbine Hort. var. **Crimsonstar**	Carmine-**red**	20
Dictam'nus al'bus **Gasplant Dittany**	**White**	32
Dictam'nus al'bus, **Gasplant Dittany** Hort. var. **Ruber** (*purpureus*)	Lilac-**mauve**	48



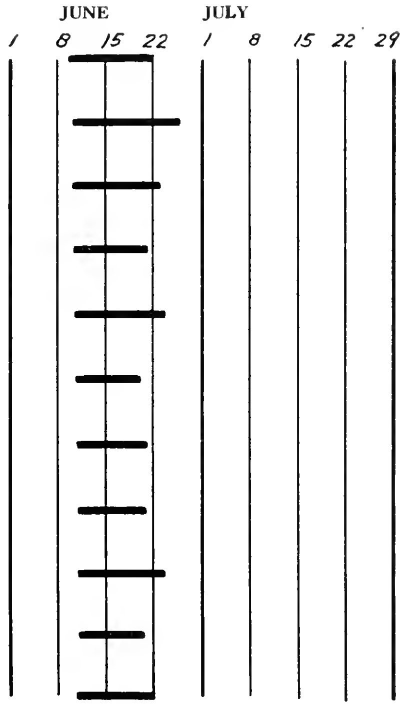
Hemerocal'lis, **Daylily** Hort. var. **Modesty**	Pale lemon-**yellow**	36
I'ris (TB) **Buechley Giant**	**Blue** self	48
I'ris (TB) **Jerry**	**Red** toned bicolor	30
I'ris (TB) **Purple Giant**	Dark **purple** self	34
Chrysan'themum coccin'eum, **Florists Pyrethrum** Hort. var. **Buckeye**	Deep **rose**, center ivory	26
Hemerocal'lis, **Daylily** Hort. var. **Apricot**	**Yellow**	36
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Fairy**	Shrimp-**pink**	32
Chrysan'themum coccin'eum, **Florists Pyrethrum** Hort. var. **D. C. Bliss**	Bright **rose**	36
Chrysan'themum coccin'eum, **Florists Pyrethrum** Hort. var. **Pinkbouquet**	Deep **rose**	30
Chrysan'themum max'imum, **Pyrenees Chrysanthemum** Hort. var. **Whiteswan**	**White**	26
Gypsoph'ila re'pens*, **Creeping Gypsophila Hort. var. **Rosy** (*rosea*)	Pale rose-**pink**	8
I'ris sibir'ica **Siberian Iris**	Dark **violet**	25
Paeo'nia, **Peony** Hort. var. **The Bride** (Lafiancee) 8.4 Single Type	Pure **white**, yellow stamens	36



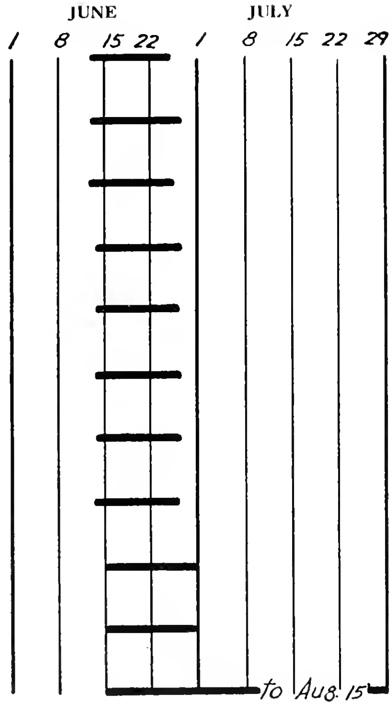
	COLOR	HEIGHT INCHES
I'ris (TB) **Ethelwynn Dubuar**	Pink-**lavender** self	36
I'ris (TB) **Gudrun**	Warm **white**	30
I'ris (TB) **King Tut**	Dark **yellow** toned blend	28
I'ris (TB) **Venus de Milo**	Cool **white**	36
Baptis'ia austra'lis **Blue Wildindigo**	Dull blue-**violet**	38
I'ris (TB) **Mary Geddes**	**Pink to red** toned blend	34
* *Helian'themum nummula'rium* Hort. var. **Buttercup**	Lemon-**yellow**	6
Hemerocal'lis auranti'aca **Orange Daylily**	**Orange** tinged red	24
Hemerocal'lis, **Daylily** Hort. var. **Aureole**	Cadmium-**yellow**	36
Hemerocal'lis fla'va **Lemon Daylily**	**Yellow**	40
Heu'chera sanguin'ea, **Coralbells** Hort. var. **Light of Allah**	Deep **pink**	24
I'ris (TB) **Mrs. Valerie West**	Purple-**red** self	36
I'ris (TB) **Rameses**	Light **pink** toned blend	36
Lupi'nus polyphyl'lus, **Washington Lupine** Hort. var. **Russell Hybrids**	**Variable**	36
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Hercules**	Bright **orange**	38



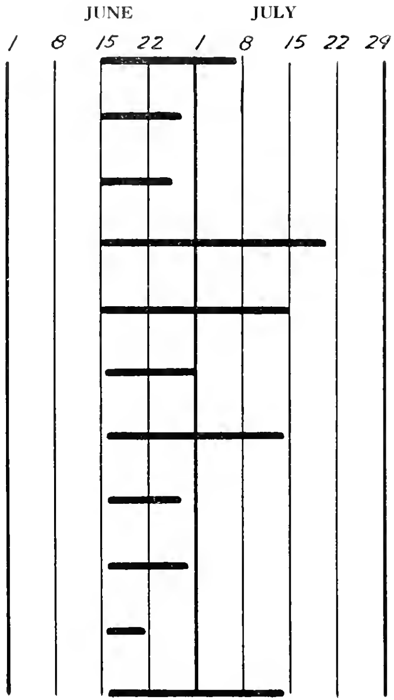
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Mrs. John Harkness**	**Pink**	28
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Princess Ena**	**Pink**	36
Potentil'la rec'ta war'reni **Warrens Sulfur Cinquefoil**	Lemon-**yellow**	20
Chrysan'themum coccin'eum, **Florists Pyrethrum** Hort. var. **Victoria**	Deep **red**	26
Paeo'nia, **Peony** Hort. var. **Cherry Hill** 8.6 Double Type	Deep **garnet**	36
Paeo'nia, **Peony** Hort. var. **Monsieur Jules Elie** 9.2 Double Type	Light rose-**pink**	36
Lysimach'ia puncta'ta **Spotted Loosestrife**	Bright **yellow**	28
Achille'a millefo'lium rose'um **Pink Common Yarrow**	Rose-**red**	30
Digita'lis ambigu'a **Yellow Foxglove**	Pale **yellow**	30
Lych'nis visca'ria*, **Clammy Campion Hort. var. **Double Rosepink** (*splendens florepleno*)	Deep **rose**	15
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Flanders**	**Red**	40



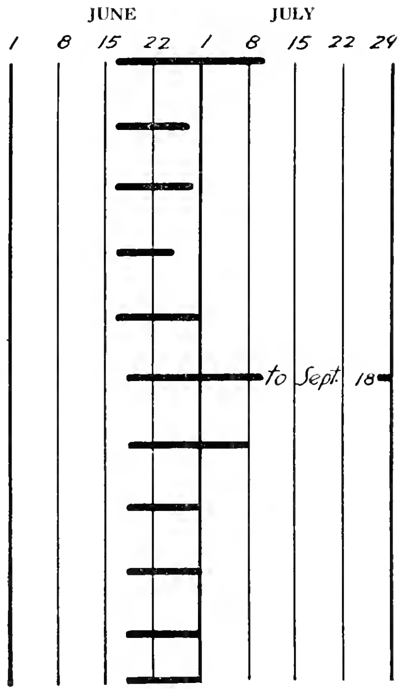
	COLOR	HEIGHT INCHES
Paeo'nia, **Peony** Hort. var. **Helen** 9.0 Single Type	Deep shell-**pink**, yellow stamens	36
Paeo'nia, **Peony** Hort. var. **Lecygne** 9.9 Double Type	**White**	32
Paeo'nia, **Peony** Hort. var. **Richard Carvel** 8.8 Double Type	**Red**	32
I'ris sibir'ica, **Siberian Iris** Hort. var. **Turquoise Cup**	Light **blue**	30
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Enfield Beauty**	Peach-**orange**	29
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Gold of Ophir**	Yellow-**orange**	30
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Perfection**	Salmon-**pink**	34
I'ris sibir'ica, **Siberian Iris** Hort. var. **Caezars Brother**	Deepest violet-**blue**	36
Paeo'nia, **Peony** Hort. var. **Pride of Essex** 8.9 Double Type	Deep shell-**pink**, suffusion of yellow at center	36
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Henri Cayeux**	Lavender-**violet**	36
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Mrs. H. G. Stobart**	**Old rose**	32



******Al'lium mo'ly* **Lily Leek**	Lemon-**yellow**	10
Paeo'nia, **Peony** Hort. var. **Festiva Maxima** 9.3 Double Type	Ivory-**white,** occasional crimson fleck	42
Paeo'nia, **Peony** Hort. var. **Frances Willard** 9.1 Double Type	Cream-**white**	34
Paeo'nia, **Peony** Hort. var. **Karl Rosenfield** 8.8 Double Type	Dark **crimson**	38
Paeo'nia, **Peony** Hort. var. **Katharine Havemeyer** 9.0 Double Type	Light rose-**pink**	32
Paeo'nia, **Peony** Hort. var. **Reine Hortense** 8.7 Double Type	Flesh-**pink**	42
Paeo'nia, **Peony** Hort. var. **Therese** 9.8 Double Type	Shell-**pink,** lighter center	36
Paeo'nia, **Peony** Hort. var. **Walter Faxon,** 9.3 Double Type	Vivid shell-**pink**	30
As'ter subcoeru'leus*, **East Indies Aster Hort. var. **Star of Eisenach**	Light blue-**violet**	18
Filipen'dula hexapet'ala, **Dropwort** Hort. var. **Double** (*florepleno*)	**Ivory**	22
Gaillar'dia arista'ta, **Common Perennial Gaillardia** Hort var. **Barnes Ruby**	Dark **red**	26

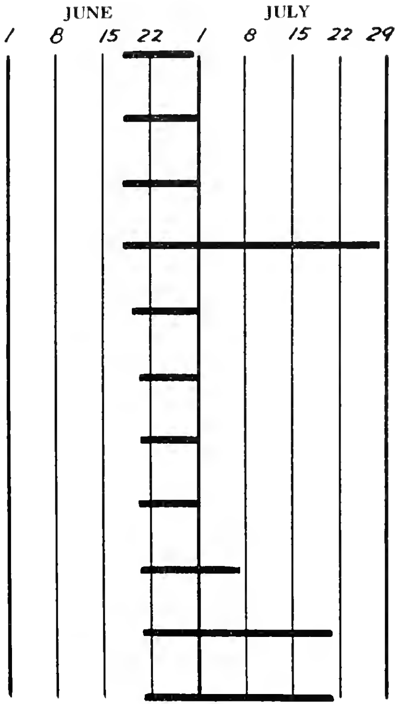


	COLOR	HEIGHT INCHES
Hemerocal'lis, Daylily Hort. var. **Winsome**	**Yellow**	36
Paeo'nia, Peony Hort. var. **Jules Calot** 7.2 Double Type	Deep rose-**pink**	30
Paeo'nia, Peony Hort. var. **King of England** 8.6 Japanese Type	**Red**, cushion of yellow-red stamens	36
Thy'mus serpyl'lum*, **Mother-of-thyme Hort. var. **White** (*albus*)	**White**	2
Veron'ica spica'ta al'ba* **White Spike Speedswell	**White**	15
Alys'sum argen'teum* **Yellowtuft Alyssum	Bright **yellow**	15
Clem'atis integrifo'lia **Solitary Clematis**	Violet-**blue**	20
Paeo'nia, Peony Hort. var. **Ama-no-sode** 9.2 Japanese Type	Bright rose-**pink**, cushion of yellow-pink stamens	36
Paeo'nia, Peony Hort. var. **Primevere** 8.6 Double Type	Guard petals **cream**, center petals ivory	36
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Goliath**	Scarlet-**orange**	24
Sal'via nemoro'sa **Violet Sage**	Blue-**violet**	28



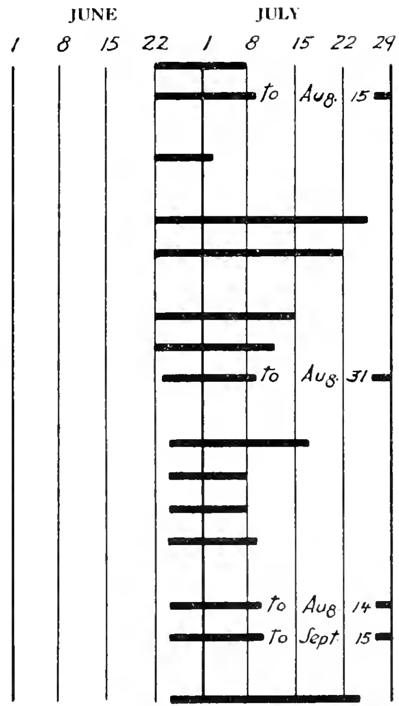
Oenothe'ra frutico'sa* **Common Sundrops Hort. var. **Youngs** (*youngi*)	Lemon-**yellow**	20
Paeo'nia, **Peony** Hort. var. **Currant** (Currant Red)** Japanese Type	Cerise-**red**, cushion of yellow-red stamens	27
Paeo'nia, **Peony** Hort. var. **Tokio** 8.9 Japanese Type	Rose-**pink**, cushion of yellow-pink stamens	36
Papa'ver orienta'le, **Oriental Poppy** Hort. var. **Sass Pink**	Pale-**pink**	38
Trol'lius ledebour'i, **Ledebour Globeflower** Hort. var. **Golden Queen**	Yellow-**orange**	18
Gaillar'dia arista'ta, **Common Perennial Gaillardia** Hort. var **Mr. Sherbrook**	**Yellow**	30
Lil'ium umbella'tum **Western Orangecup Lily**	Orange-**red**	22
Paeo'nia, **Peony** Hort. var. **Avalanche** 8.7 Double Type	Ivory-**white**	36
Paeo'nia, **Peony** Hort. var. **Cornelia Shaylor** 9.1 Double Type	Guard petals soft **white**, shell-pink center	36
Paeo'nia, **Peony** Hort. var. **Edward VII**** Japanese Type	**Red**, cushion of yellow-red stamens	36
Paeo'nia, **Peony** Hort. var. **Elsa Sass** ** Double Type	**White**	36

**Not yet rated.



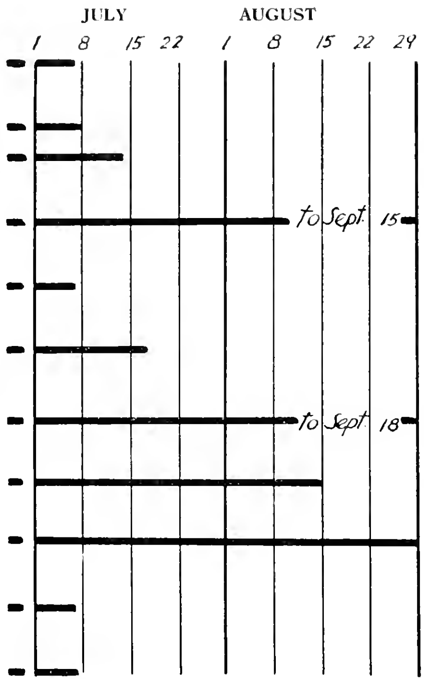
	COLOR	HEIGHT INCHES
Paeo'nia, **Peony** Hort. var. **Isani Gidui** 9.3 Japanese Type	Pure **white**, cushion of golden stamens	32
Paeo'nia, **Peony** Hort. var. **Mme. Emile Galle** 8.5 Double Type	Light rose-**pink**	36
Paeo'nia, **Peony** Hort. var. **Nick Shaylor** 9.2 Double Type	Cream-**white**, delicate pink lights	30
Prunel'la webbia'na* **Webb Selfheal	Lilac-**rose**	9
Paeo'nia, **Peony** Hort. var. **Dog Rose** 7.9 Japanese Type	Rose-**pink**, cushion of yellow-rose stamens	32
Lil'ium daur'icum **Dahurian Lily**	Red-**orange**	27
Paeo'nia, **Peony** Hort. var. **Aureolin** 8.9 Japanese Type	**Pink** guard petals, center yellow petaloides	30
Paeo'nia, **Peony** Hort. var. **Soshi**** Japanese Type	Deep **crimson**, cushion of yellow-crimson stamens	30
Thermop'sis carolinia'na **Carolina Thermopsis**	Lemon-**yellow**	48
Phlox' arends'i*, **Arends Phlox Hort. var. **Inga**	Blue-**lavender**	18
Veron'ica spica'ta **Spike Speedwell**	Light violet-**blue**	18

****Not yet raled.**



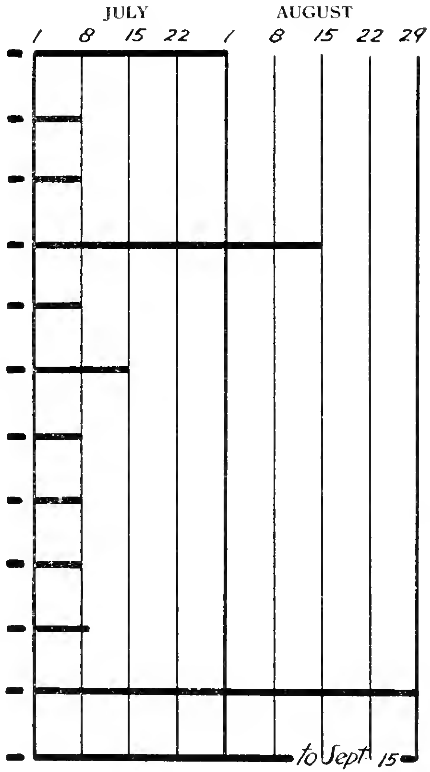
**Campan'ula garga'nica*	**Blue**	5
† Heu'chera sanguin'ea, **Coralbells** Hort. var. **Sanglant**	Bright **red**	20
Lil'ium umbella'tum, **Western Orangecup Lily** Hort. var. **Feu Brilliant**	Deep **red**	19
Mal'va moscha'ta, **Musk Mallow**	Lilac-**rose to white**	30
Pen'stemon barba'tus, **Beardlip Penstemon** Hort. var. **Pink Beauty**	Clear **pink**	30
Veron'ica inca'na*, **Woolly Speedwell	Light blue-**violet**	15
Veron'ica spica'ta rose'a*, **Pink Spike Speedwell	Light rose-**pink**	16
Heliop'sis sca'bra, **Rough Heliopsis** Hort. var. **Incomparabilis**	Bright orange-**yellow**	40
Erig'eron caucas'icus*, **Caucasian Fleabane	Pale lavender-**violet**	10
Lil'ium el'egans, **Thunberg Lily**	**Orange**	22
Lil'ium han'soni, **Hanson Lily**	Light **yellow**	48
Lil'ium umbella'tum, **Western Orangecup Lily** Hort. var. **Umbel Incomparabile**	**Red and orange**	24
Scabio'sa caucas'ica, **Caucasian Scabious**	Gray-**blue**	24
Coreop'sis grandiflo'ra, **Bigflower Coreopsis** Hort. var. **Sunburst**	Bright **yellow**	30
Lych'nis corona'ria, **Rose Campion**	Bright purple-**red**	26

SUMMER SECTION (JULY–AUGUST)

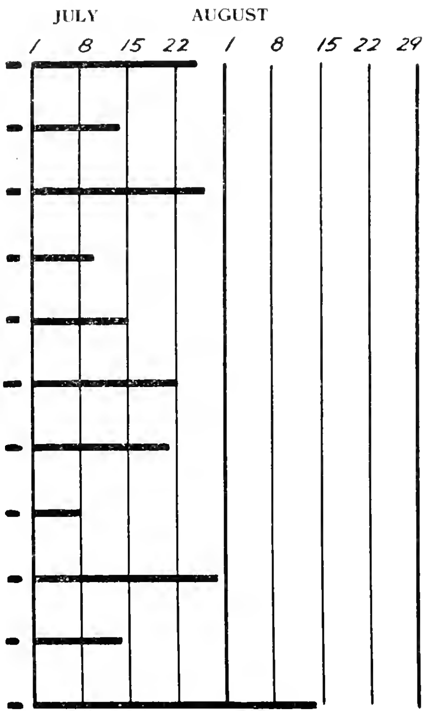


	COLOR	HEIGHT INCHES
Achille'a millefo'lium rose'um **Pink Common Yarrow**	Rose-**red**	30
**Campan'ula garga'nica*	**Blue**	5
Clem'atis integrifo'lia **Solitary Clematis**	Violet-**blue**	20
Coreop'sis grandiflo'ra, **Bigflower Coreopsis** Hort. var. **Sunburst**	Bright **yellow**	30
Digita'lis ambig'ua **Yellow Foxglove**	Pale **yellow**	30
Erig'eron caucas'icus* **Caucasian Fleabane	Pale lavender-**violet**	10
Gaillar'dia arista'ta, **Common Perennial Gaillardia** Hort. var. **Mr. Sherbrook**	**Yellow**	30
Gaillar'dia arista'ta, **Common Perennial Gaillardia** Hort. var. **Barnes Ruby**	Dark **red**	26
Heliop'sis sca'bra, **Rough Heliopsis** Hort. var. **Incomparabilis**	Bright orange-**yellow**	40
Hemerocal'lis, **Daylily** Hort. var. **Winsome**	**Yellow**	36
Heu'chera sanguin'ea, **Coralbells** Hort. var. **Cathedral Bells**	Bright rose-**red**, white base	30

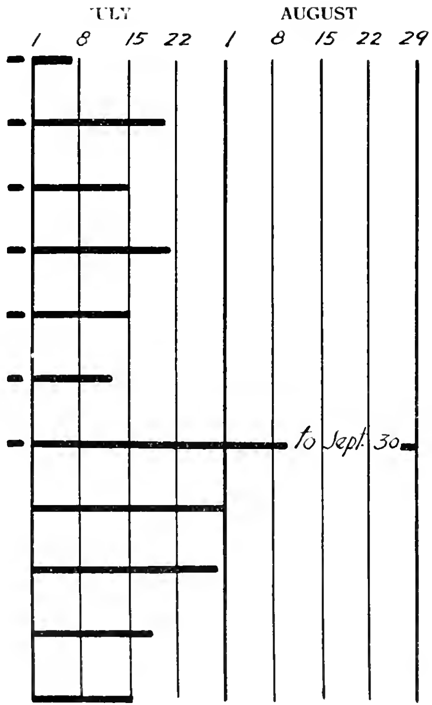
— before graph indicates continuation of bloom from Spring Section.



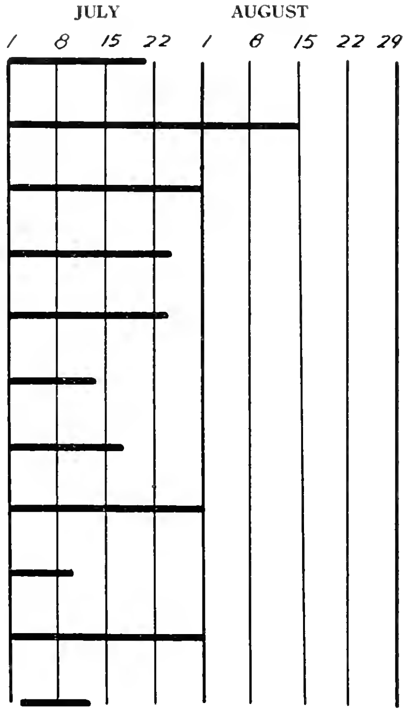
Heu'chera sanguin'ea, Coralbells Hort. var. **Garnet**	Light **pink**	21
Heu'chera sanguin'ea, Coralbells Hort. var. **Jubilee**	Pale **pink**	26
Heu'chera sanguin'ea, Coralbells Hort. var. **Light of Allah**	Deep **pink**	24
† *Heu'chera sanguin'ea*, Coralbells Hort. var. **Sanglant**	Bright **red**	20
Heu'chera sanguin'ea, Coralbells Hort var. **Pluie de Feu**	**Red**	25
† *Heu'chera sanguin'ea*, Coralbells Hort. var. **Snowflake**	Pure **white**	29
Lil'ium el'egans **Thunberg Lily**	**Orange**	22
Lil'ium han'soni **Hanson Lily**	Light **yellow**	48
Lil'ium umbella'tum **Western Orangecup Lily**	Orange-**red**	22
Lil'ium umbella'tum, **Western Orangecup Lily** Hort. var. **Umbel Incomparabile**	**Red and orange**	24
* *Lo'tus cornicula'tus* **Birdsfoot Deervetch**	**Yellow** tinged red	15
* *Lo'tus siliquo'sus*	Lemon-**yellow**	12



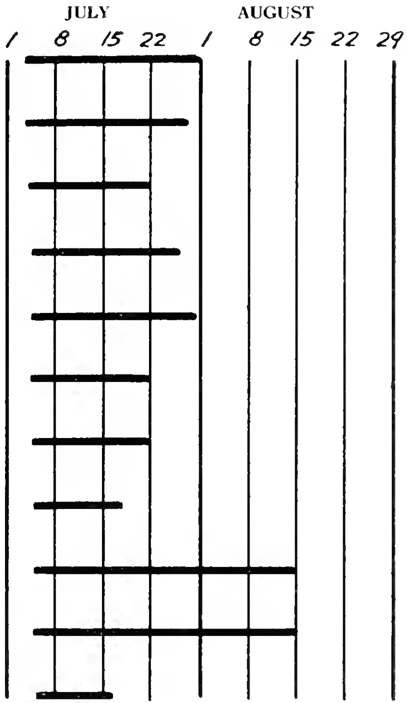
	COLOR	HEIGHT INCHES
Lych'nis corona'ria **Rose Campion**	Bright purple-red	26
Lysimach'ia puncta'ta **Spotted Loosestrife**	Bright yellow	28
Mal'va moscha'ta **Musk Mallow**	Lilac-rose to white	30
Oenothe'ra frutico'sa*, **Common Sundrops Hort. var. **Youngs** (*youngi*)	Lemon-yellow	20
Papa'ver schinzia'num **Schinz Poppy**	Light orange	26
Pen'stemon barba'tus, **Beardlip Penstemon** Hort. var. **Pink Beauty**	Clear pink	30
Phlox' arends'i*, **Arends Phlox Hort. var. **Inga**	Blue-lavender	18
Potentil'la rec'ta war'reni **Warrens Sulfur Cinquefoil**	Lemon-yellow	20
Prunel'la webbia'na* **Webb Selfheal	Lilac-rose	9
Sal'via nemoro'sa **Violet Sage**	Blue-violet	28
Scabio'sa caucas'ica **Caucasian Scabious**	Gray-blue	24



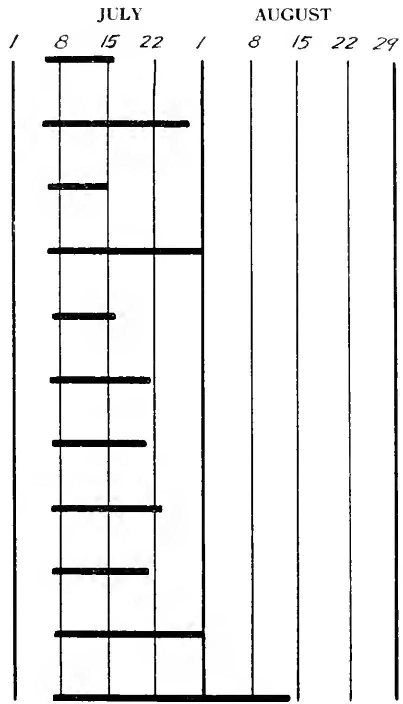
Thermop'sis carolinia'na **Carolina Thermopsis**	Lemon-**yellow**	48
Thy'mus serpyl'lum*, **Mother-of-thyme Hort. var. **White** (*albus*)	**White**	2
Veron'ica inca'na* **Woolly Speedwell	Light blue-**violet**	15
Veron'ica spica'ta **Spike Speedwell**	Light violet-**blue**	18
Veron'ica spica'ta al'ba* **White Spike Speedwell	**White**	15
Veron'ica spica'ta rose'a* **Pink Spike Speedwell	Light rose-**pink**	16
†*Vio'la cornu'ta*, **Horned Violet** Hort. var. **Fragrance**	Blue-**violet**	6
Aconi'tum napel'lus **Aconite Monkshood**	Blue-**violet**	42
Al'lium stella'tum **Prairie Onion**	Pale **lavender**	25
An'themis tincto'ria, **Golden Camomile** Hort. var. **Moonlight**	**Yellow**	24
Astil'be, **Astilbe** Hort. var. **Fanol** (Fanal)	Deep **red**	20



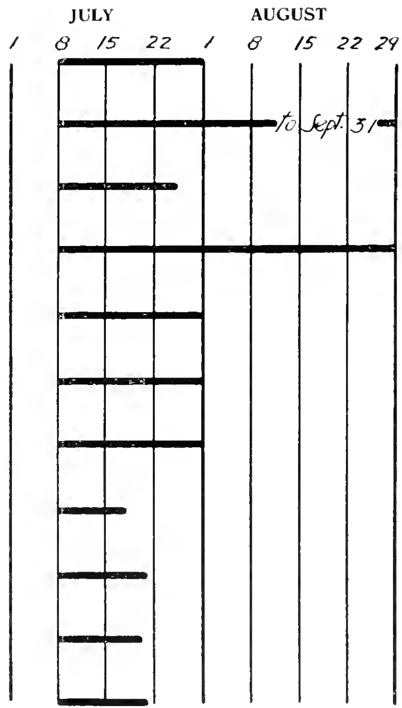
	COLOR	HEIGHT INCHES
Delphin'ium grandiflo'rum chinen'se **Slender Siberian Larkspur**	Bright **blue**	30
Gypsoph'ila re'pens*, **Creeping Gypsophila Hort. var. **Bodger** (*bodgersi*)	Pale lavender-**pink**	16
Hemerocal'lis ful'va **Tawny Daylily**	**Orange**	48
Lavan'dula officina'lis **True Lavender**	Light lavender-**violet**	24
Pen'stemon tor'reyi **Torrey Penstemon**	Scarlet-**red**	24
Astil'be, **Astilbe** Hort. var. **Avalanche**	**Ivory**	26
Phlox' glaber'rima, **Smooth Phlox** Hort. var. **Miss Lingard**	**White,** slight rose shading at center	34
Se'dum al'bum* **White Stonecrop	**White**	7
Thalic'trum glau'cum **Dusty Meadowrue**	Lemon-**yellow**	60
Tradescan'tia virginia'na, **Virginia Spiderwort** Hort. var. **James Stratton**	Light **violet**	36
Lil'ium el'egans, **Thunberg Lily** Hort. var. **Shedd**	Dull **red**	27



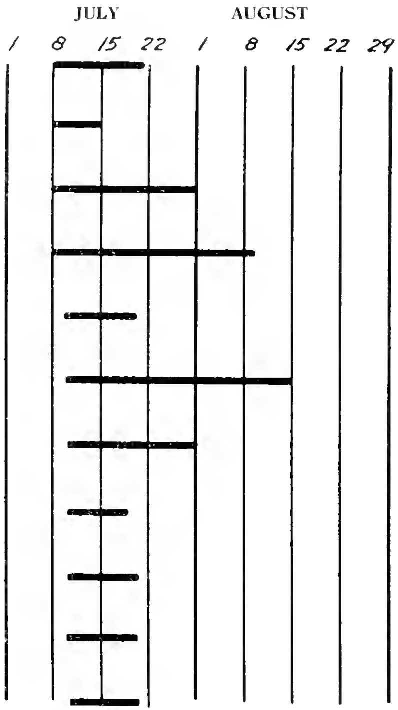
Achille'a filipenduli'na, **Fernleaf Yarrow** Hort. var. **Parkers**	Bright **yellow**	48
Chrysan'themum max'imum, **Pyrenees Chrysanthemum** Hort. var. **Victor**	**White**	30
Hemerocal'lis, **Daylily** Hort. var. **Bagdad**	**Red over orange**	36
Anthe'ricum lilia'go **St. Bernardlily**	**White**	40
Campan'ula glomera'ta dahur'ica **Dahurian Bellflower**	**Violet**	18
Hemerocal'lis, **Daylily** Hort. var. **Bijou**	**Red over orange**	32
Hemerocal'lis, **Daylily** Hort. var. **Mikado**	Orange-**yellow**, large mahogany blotch	28
Monar'da rama'leyi **Ramaley Beebalm**	**Lilac**	32
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Columbia**	Bright **pink**	24
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Jules Sandeau**	Bright **rose**	24
I'ris kaemp'feri, **Japanese Iris** Hort. var. **Goldbound**	**White**, yellow mid-vein	28



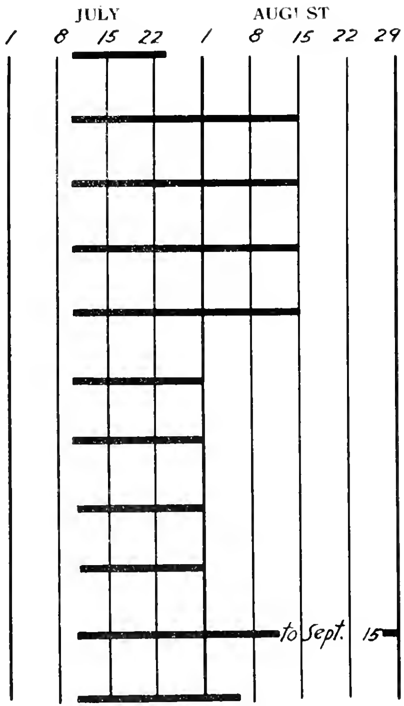
	COLOR	HEIGHT INCHES
Lil'ium columbia'num **Columbia Lily**	Orange	32
* *Veron'ica latifo'lia (teucrium)*, **Hungarian Speedwell** Hort. var. **Rupestris**	Violet-**blue**	16
I'ris kaemp'feri, **Japanese Iris** Hort. var. **Wister's Favorite**	Light **blue**, deeper throat	27
* *Veron'ica inca'na*, **Woolly Speedwell** Hort. var. **Rose** (*rosea*)	**Pink,** gray foliage	18
I'ris kaemp'feri, **Japanese Iris** Hort. var. **Painted Lady**	**Lilac on white**	22
I'ris kaemp'feri, **Japanese Iris** Hort. var. **Purple and Gold**	Deep **purple,** yellow midvein	36
Lil'ium canaden'se **Canada Lily**	**Yellow,** purple spotted	38
Lil'ium rega'le **Regal Lily**	**White**	42
Mal'va al'cea **Hollyhock Mallow**	**Rose to white**	36
Monar'da did'yma, **Oswego Beebalm** Hort. var. **Cambridge Scarlet**	Bright **red**	36
Veron'ica marit'ima (longifolia) Hort. var. **Blue Spire**	Violet-**purple**	24



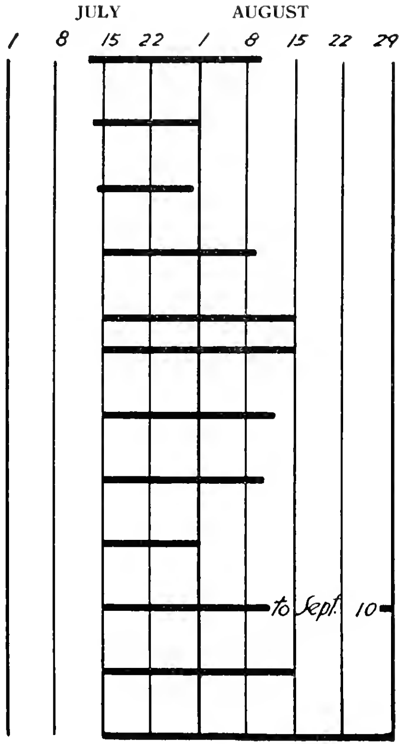
Chrysan'themum max'imum, Pyrenees Chrysanthemum Hort. var. **Admiral Byrd**	**White**	30
Gaillar'dia arista'ta **Common Perennial Gaillardia**	**Yellow and red**	22
Gypsoph'ila panicula'ta, Babysbreath Hort. var. **Double** (*floreplenо*)	**White**	38
Heliop'sis sca'bra Rough Heliopsis Hort. var. **Zinnia** (*zinniaeflora*)	Orange-**yellow**	40
Hemerocal'lis, Daylily Hort. var. **Burgundy**	**Maroon**	32
Hemerocal'lis, Daylily Hort. var. **Serenade**	Rose-**yellow**, definite green tone	48
Hemerocal'lis, Daylily Hort. var. **Soudan**	**Yellow**	36
I'ris kaemp'feri, Japanese Iris Hort. var. **Akafukurin**	**White**, red-purple edged	22
I'ris kaemp'feri, Japanese Iris Hort. var. **America**	**White**, deep purple edged	42
I'ris kaemp'feri, Japanese Iris Hort. var. **Carleton Childs**	Violet-**blue veined over white**	36
I'ris kaemp'feri, Japanese Iris Hort. var **Fanny Hamlet Childs**	**Purple**, white streaked	36



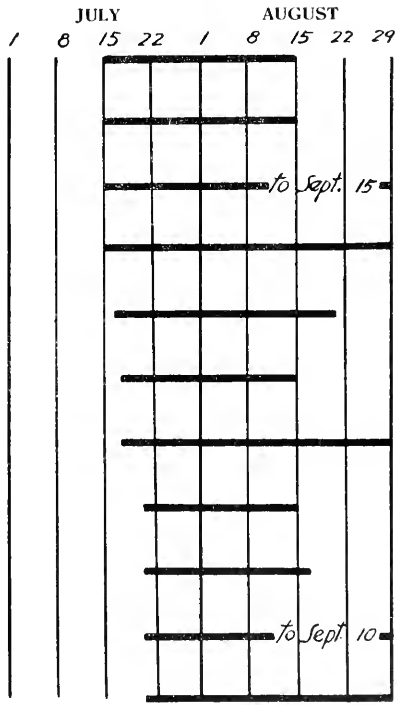
Plant	Color	Height Inches
I'ris kaemp'feri, **Japanese Iris** Hort. var. **Redridinghood**	Wine-**red**	27
Lil'ium testa'ceum **Nankeen Lily**	Light **apricot**	54
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Eva Foerster**	Bright rose-**pink**	22
Stoke'sia lae'vis, **Stokesia** Hort. var. **Big Lilac** (*lilacina grandiflora*)	Blue-**lavender**	20
Centau'rea macroceph'ala **Globe Centaurea**	Lemon-**yellow**	36
Coreop'sis verticilla'ta **Threadleaf Coreopsis**	Bright **yellow**	26
Hemerocal'lis, **Daylily** Hort. var. **The Gem**	**Yellow**	40
I'ris kaemp'feri, **Japanese Iris** Hort. var. **Lester Lovett**	Violet-**blue**, white center	30
I'ris kaemp'feri, **Japanese Iris** Hort. var. **Mahogany**	Dark purple-**red**	30
I'ris kaemp'feri, **Japanese Iris** Hort. var. **Norma**	Light **pink**	36
I'ris kaemp'feri, **Japanese Iris** Hort. var. **Shinso-kajin**	**White**, blue tinge	36



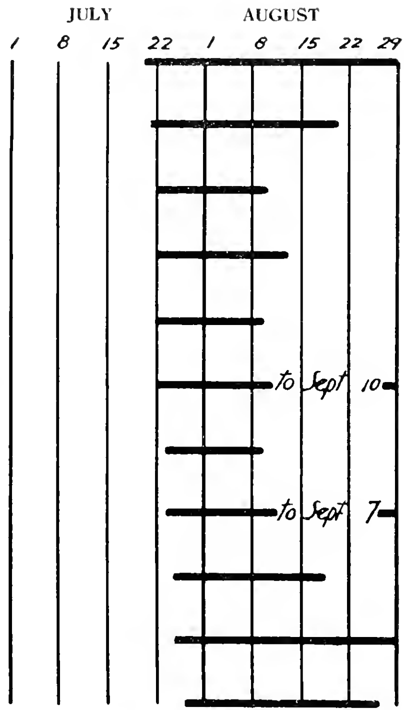
I'ris kaemp'feri, **Japanese Iris** Hort. var. **Violet Beauty**	Deep **purple**	36
Phlox' panicula'ta, **Summer Phlox** Hort var **Antonin Mercier**	**Lilac over white**	34
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Graf Zepplin**	**White,** crimson eye	34
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Mary Louise**	**White**	24
Physoste'gia virginia'na, **Virginia Lionsheart** Hort. var. **White** (*alba*)	**White**	32
Platyco'don grandiflo'rum **Balloonflower**	Blue-**violet**	36
Platyco'don grandiflo'rum, **Balloonflower** Hort. var. **White** (*album*)	**White**	36
Astil'be, **Astilbe** Hort. var. **Gloria**	Deep **rose**	36
Astil'be, **Astilbe** Hort. var. **Irene Rottsieper**	Light **pink**	26
Achille'a ptar'mica, **Sneezewort Yarrow** Hort. var. **Perry White**	**White**	18
Hemerocal'lis, **Daylily** Hort. var. **Donald Wyman**	Orange-**yellow,** pale rust-red blotch at center	28



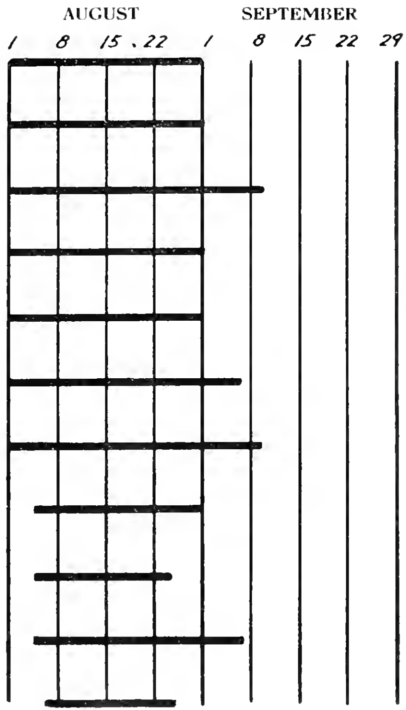
	COLOR	HEIGHT INCHES
Hemerocal'lis, **Daylily** Hort. var. **Goldeni**	**Orange**	36
Monar'da did'yma, **Oswego Beebalm** Hort. var. **Salmon** (*salmonea*)	**Pink**	36
Al'lium fla'vum* **Yellow Onion	**Yellow**	14
Campan'ula carpa'tica* **Carpathian Bellflower	Violet-**blue**	10
Eryn'gium pla'num	Metallic **blue**	34
Hemerocal'lis, **Daylily** Hort. var. **Festival**	Red-**brown,** yellow center	36
Hemerocal'lis, **Daylily** Hort. var. **Goldendream**	Orange-**yellow**	40
Hemerocal'lis, **Daylily** Hort. var. **Hyperion**	**Yellow,** slight green tone	36
Lia'tris pycnosta'chya **Kansas Gayfeather**	Light **purple**	34
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Flash**	Purple-**red**	36
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Hauptmann Kohl**	Bright rose-**red**	30
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Mrs. Milly Vanhoboken**	Light rose-**pink,** darker center	30



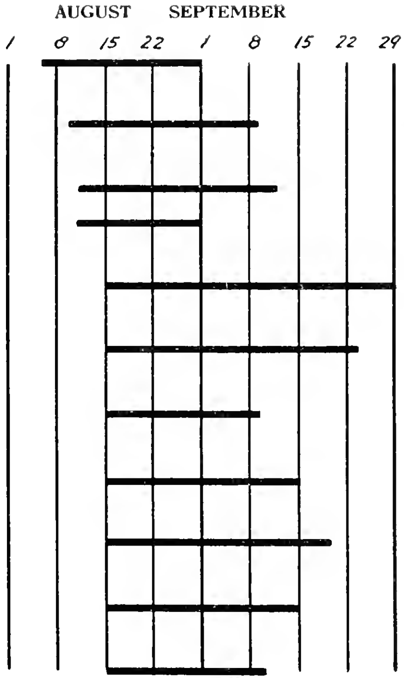
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Painted Lady**	Pale **pink on white**	27
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Salmon Glow**	Bright salmon-**pink**	30
Tu'nica saxif'raga* **Saxifrage Tunicflower	Pale lilac-rose blush on **white**	8
Thy'mus serpyl'lum* **Mother-of-thyme	Lavender-**pink**	6
I'ris dichot'oma **Vesper Iris**	**Lavender**	36
E'chinops ri'tro **Small Globethistle**	Light **blue**	54
Lysimach'ia clethroi'des **Clethra Loosestrife**	**White**	30
Lia'tris spica'ta **Spike Gayfeather**	Pink-**lavender**	36
Phlox' panicula'ta, **Summer Phlox** Hort var. **Cameron**	Rose-**lilac over white**	36
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Mia Ruys**	**White**	16
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Rosenkavalier**	Deep rose-**pink**	30



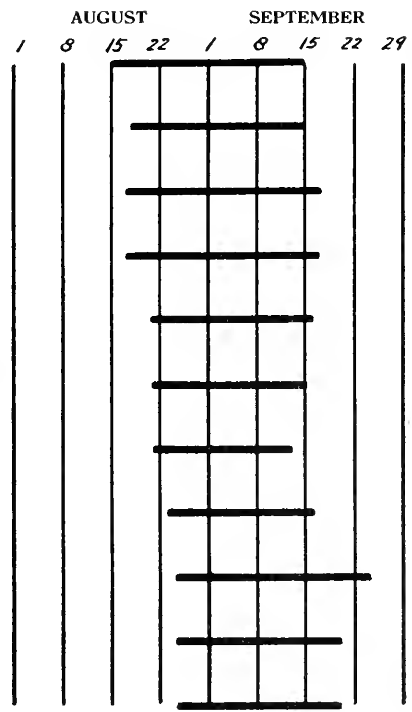
	COLOR	HEIGHT INCHES
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Widar**	Violet-**purple** white center	34
Phlox' panicula'ta, **Summer Phlox** Hort. var. **E. I. Farrington**	**Pink**	36
Hemerocal'lis ful'va, **Tawny Daylily** Hort. var. **Maculata**	Light orange-**red**, yellow center	40
Hemerocal'lis, **Daylily** Hort. var. **Rajah**	Dark orange-**red**	40
Hemerocal'lis, **Daylily** Hort. var. **Rose Queen**	Pale red-**brown**	36
Rudbeck'ia ni'tida Hort. var. **Autumn Sun**	Bright **yellow**	72
Belamcan'da chinen'sis **Blackberrylily**	**Orange**, red speckled	33
Echina'cea purpu'rea, **Purple Echinacea** Hort. var. **The King**	Rose-**pink**, center a red-orange cone	54
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Lemahdi**	Deep **purple**	30
Aconi'tum napel'lus, **Aconite Monkshood** Hort. var. **Sparks**	Dark blue-**violet**	56
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Augusta**	Magenta-**purple**	18



Coreop'sis trip'teris Atlantic Coreopsis	Yellow	84
Lil'ium tigri'num Tiger Lily	Orange, brown speckled	36
Lobe'lia cardina'lis Cardinalflower	Cardinal-red	32
Phlox' panicula'ta, Summer Phlox Hort. var. Dr. Klemm	Blue-violet over white	20
Phlox' panicula'ta, Summer Phlox Hort. var. W. C. Egan	Light rose	18
Rudbeck'ia lacinia'ta, Cutleaf Coneflower Hort. var. Goldenglow (*floreplena*)	Bright yellow	60
Rudbeck'ia specio'sa (*newmanni*) Showy Coneflower	Orange-yellow	24
Euphor'bia corolla'ta Floweringspurge Euphorbia	White	48
Lil'ium hen'ryi Henry Lily	Yellow-orange, few brown specks	72
Phlox' panicula'ta, Summer Phlox Hort. var. Ruth May	True light pink	30
Phlox' panicula'ta, Summer Phlox Hort. var. Border Gem	Purple	24

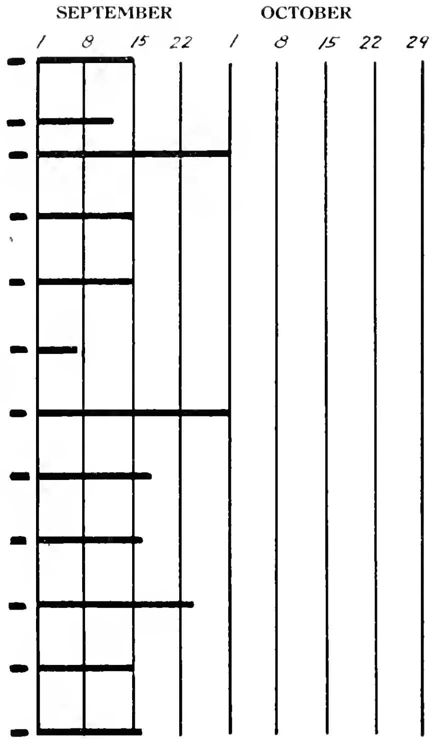


	COLOR	HEIGHT INCHES
Physoste'gia virginia'na **Virginia Lionsheart**	Pale **lavender**	58
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Czarina**	**White**	42
**Al'lium monta'num glau'cum*	Pale **lilac**	12
Lil'ium tigri'num, **Tiger Lily** Hort. var. **Tiger Double** (*floreplenο*)	**Orange,** brown speckled	36
As'ter amel'lus el'egans* **Low Italian Aster	**Violet,** long yellow stamens	18
Hele'nium autumna'le, **Common Sneezeweed** Hort. var. **Chipperfield Orange**	**Yellow,** red-rust flush	36
Veron'ica marit'ima (longifolia) subses'silis **Clump Speedwell**	Purple-**blue**	32
Hele'nium bigelo'vi **Bigelow Sneezeweed**	Sulfur-**yellow**	40
Phlox' panicula'ta, **Summer Phlox** Hort. var. **B. Comte**	Deep purple-**red**	30
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Charles B. Merrill**	Salmon-rose-**pink**	42
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Harvest Fire**	Salmon-**pink**	38



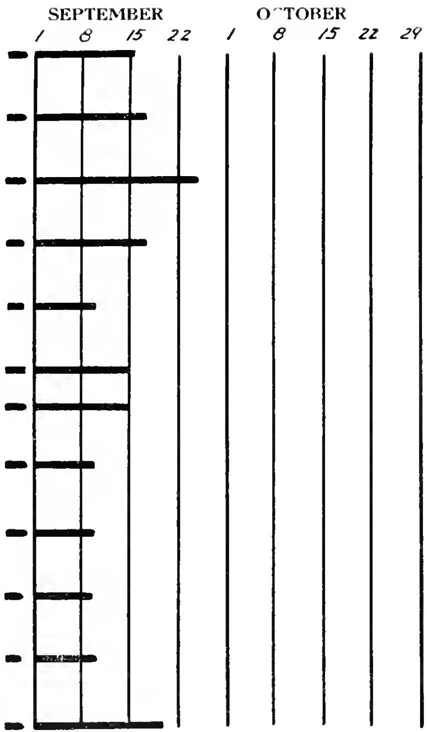
Saturei'a monta'na* **Winter Savory	**White**	12
Chelo'ne ly'oni **Pink Turtlehead**	Deep rose-**pink**	44
Lil'ium specio'sum, **Speciosum Lily** Hort. var. **Speciosum Magnificum**	Rose-**red on white**	36
Lil'ium specio'sum ru'brum **Pink Speciosum Lily**	Rose-**red on white**	36
Hemerocal'lis, **Daylily** Hort. var. **August Pioneer**	Orange-**yellow**	38
Hemerocal'lis, **Daylily** Hort. var. **Boutonniere**	Orange-**yellow**	36
Verno'nia noveboracen'sis **New York Ironweed**	Violet-**purple**	80
Gypsoph'ila visco'sa, **Sticky Gypsophila** Hort. var. **Bristolfairy**	**White**	36
Lil'ium specio'sum kraet'zeri **Greenstripe Speciosum Lily**	**White,** mainrib under petals greenish	40
Se'dum spectab'ile* **Showy Stonecrop	Pale rose-**lilac**	18
Se'dum spectab'ile atropurpu'reum* **Purple Showy Stonecrop	**Rose**	16

FALL SECTION (SEPTEMBER-OCTOBER)

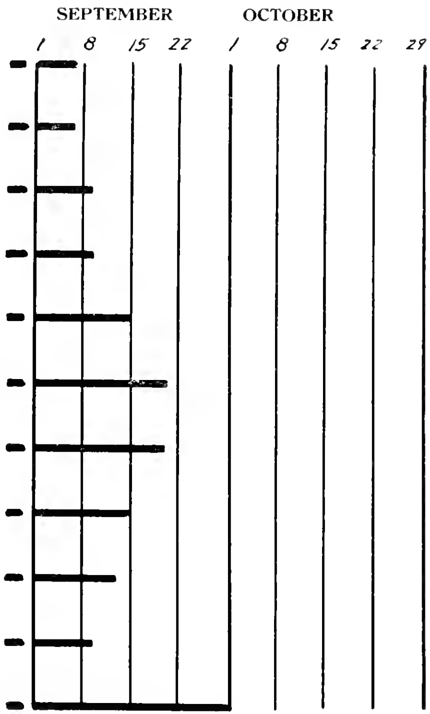


	COLOR	HEIGHT INCHES
Achille'a ptar'mica, Sneezewort Yarrow Hort. var. Perry White	White	18
**Al'lium monta'num glau'cum*	Pale lilac	12
**As'ter amel'lus el'egans* Low Italian Aster	Violet, long yellow stamens	18
Chelo'ne ly'oni Pink Turtlehead	Deep rose-pink	44
Coreop'sis grandiflo'ra, Bigflower Coreopsis Hort. var. Sunburst	Bright yellow	30
Echina'cea purpu'rea, Purple Echinacea Hort. var The King	Rose-pink, center a red-orange cone	54
Gaillar'dia arista'ta Common Perennial Gaillardia	Yellow and red	22
Gaillar'dia arista'ta, Common Perennial Gaillardia Hort. var. Mr. Sherbrook	Yellow	30
Gypsoph'ila visco'sa, Sticky Gypsophila Hort. var. Bristolfairy	White	36
Hele'nium autumna'le, Common Sneezeweed Hort. var. Chipperfield Orange	Yellow, red-rust flush	36
Hele'nium bigelo'vi Bigelow Sneezeweed	Sulfur-yellow	40
Hemerocal'lis, Daylily Hort. var. August Pioneer	Orange-yellow	38

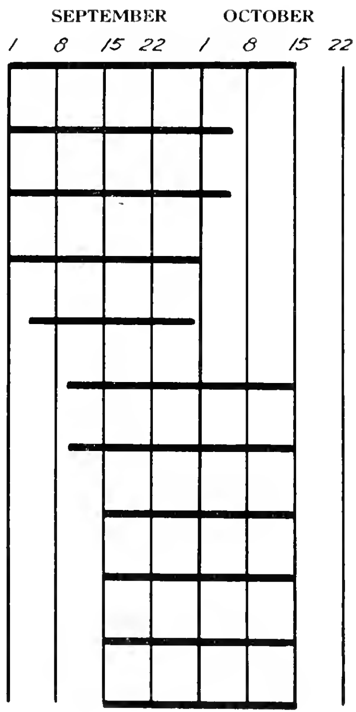
▬ before graph indicates continuation of bloom from Summer Section.



Hemerocal'lis, **Daylily** Hort. var. **Boutonniere**	Orange-**yellow**	36
Lil'ium specio'sum, **Speciosum Lily** Hort. var. **Speciosum Magnificum**	Rose-**red on white**	36
Lil'ium specio'sum kraet'zeri **Greenstripe Speciosum Lily**	**White,** mainrib under petals greenish	40
Lil'ium specio'sum ru'brum **Pink Speciosum Lily**	Rose-**red on white**	36
Lobe'lia cardina'lis **Cardinalflower**	Cardinal-**red**	32
**Lo'tus siliquo'sus*	Lemon-**yellow**	12
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Charles B. Merrill**	Salmon-rose-**pink**	42
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Czarina**	**White**	42
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Flash**	Purple-**red**	36
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Harvest Fire**	Salmon-**pink**	38
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Mia Ruys**	**White**	16
Phlox' panicula'ta, **Summer Phlox** Hort. var. **B. Comte**	Deep purple-**red**	30



	COLOR	HEIGHT INCHES
Phlox' panicula'ta, **Summer Phlox** Hort. var. **Ruth May**	True light **pink**	30
Rudbeck'ia lacinia'ta, **Cutleaf Coneflower** Hort. var. **Goldenglow** (*flore pleno*)	Bright **yellow**	60
Rudbeck'ia ni'tida Hort. var. **Autumn Sun**	Bright **yellow**	72
Rudbeck'ia specio'sa (newmanni) **Showy Coneflower**	Orange-**yellow**	24
Saturei'a monta'na* **Winter Savory	**White**	12
Se'dum spectab'ile* **Showy Stonecrop	Pale rose-**lilac**	18
Se'dum spectab'ile atropurpu'reum* **Purple Showy Stonecrop	**Rose**	16
Tu'nica saxif'raga* **Saxifrage Tunicflower	Pale lilac-rose blush on **white**	8
Verno'nia noveboracen'sis **New York Ironweed**	Violet-**purple**	80
Veron'ica mariti'ima (longifolia) subses'silis **Clump Speedwell**	Purple-**blue**	32
Vio'la cornu'ta*, **Horned Violet Hort. var. **Fragrance**	Blue-**violet**	6



Chrysan'themum, **Chrysanthemum** . . . . Light **pink** 16
Hort. var. **Clara Curtis**

Chrysan'themum, **Chrysanthemum** . . . . **White** 20
Hort. var. **Seminole**

Hemerocal'lis multiflo'ra . . . . Orange-**buff** 30
Manyflower Daylily

†*Physoste'gia virginia'na*, **Virginia Lionsheart** . . . . Rose-**lilac** 27
Hort. var. **Summer Glow**

Bolto'nia latisqua'ma . . . . Pale rosy-**lilac** 40
Violet Boltonia

Chrysan'themum, **Chrysanthemum** . . . . Lemon-**yellow** 18
Hort. var. **Pygmy Gold**

Chrysan'themum, **Chrysanthemum** . . . . **Old rose** 24
Hort. var. **Roberta Copeland**

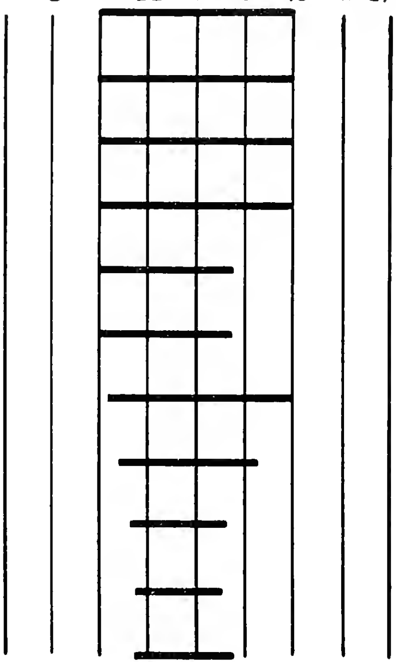
Chrysan'themum amali'ae . . . . Lilac-**pink** 20
Amalia Chrysanthemum

Chrysan'themum amali'ae, **Amalia Chrysanthemum** . . . . Rose-**bronze** 20
Hort. var. **Amalia Bronze**

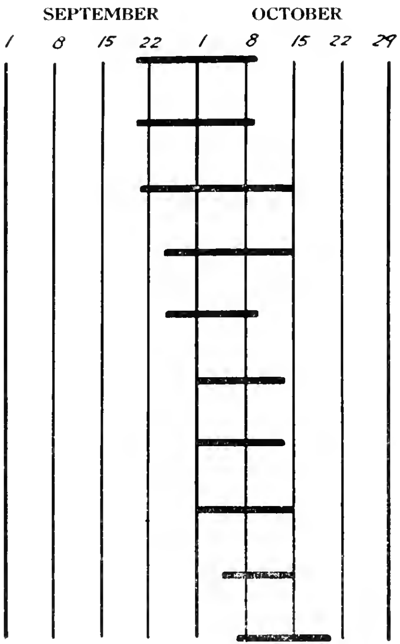
Chrysan'themum amali'ae, **Amalia Chrysanthemum** . . . . **Red** 18
Hort. var. **Amalia Red**

Chrysan'themum amali'ae, **Amalia Chrysanthemum** . . . . **White** 18
Hort. var. **Amalia White**

SEPTEMBER 1 8 15 22 — OCTOBER 1 8 15 22 29



	COLOR	HEIGHT
†*Chrysan'themum amali'ae*, **Amalia Chrysanthemum** Hort. var. **Dean Kay**	Lilac-**pink**	26
†*Chrysan'themum*, **Chrysanthemum** Hort. var. **My Lady**	**Yellow**	24
†*Chrysan'themum*, **Chrysanthemum** Hort. var. **Tasiva** (Tasvia)	**White**	26
Eupato'rium coelesti'num **Mistflower Eupatorium**	**Lavender**	28
Lia'tris scario'sa al'ba **White Tall Gayfeather**	**White**	48
Physoste'gia virginia'na, **Virginia Lionsheart** Hort. var. **Vivid**	Purple-**rose**	18
Chrysan'themum, **Chrysanthemum** Hort. var. **Algonquin**	Bright **yellow**	27
Sal'via pitch'eri (azurea grandiflora) **Pitchers Sage**	**Blue**	44
As'ter novibel'gi, **New York Aster** Hort. var. **Alderman Vokes**	**Salmon**	36
As'ter novibel'gi, **New York Aster** Hort. var. **Charles Wilson**	Ruby-**red**	36
As'ter novaean'gliae, **New England Aster** Hort. var. **Harringtons Pink**	Bright rose-**pink**	36



As'ter novibel'gi, **New York Aster** Hort. var. **Mt. Everest**	**White**	48
As'ter novibel'gi, **New York Aster** Hort. var. **Violetta**‡	Violet-**blue**	36
Chrysan'themum, **Chrysanthemum** Hort. var. **Early Bronze**	Bronze-**yellow**	24
As'ter oblongifo'lius, **Aromatic Aster** Hort. var. **Campbells Pink**	Lilac-**pink**	24
As'ter novibel'gi, **New York Aster** Hort. var. **Skylands Queen**	**Lavender**	44
As'ter novibel'gi, **New York Aster** Hort. var. **Acme**	Light lavender-**violet**	60
As'ter lae'vis, **Smooth Aster** Hort. var. **Helen Durward**	**Violet**	36
As'ter novaean'gliae, **New England Aster** Hort. var. **Survivor**	Bright rose-**pink**	36
As'ter cordifo'lius, **Heartleaf Aster** Hort. var. **Silverspray**	Pale **lilac**, mahogany colored stems	36
As'ter, **Aster** Hort var. **Burbanks Charming**	White-**pink**	53

‡Aster Violetta has been judged as the bluest of the great number tested. It is superior in blue tone to even the selected varieties Blue Plume, Blue Lagoon, Gayborder Blue, Blue Eyes, Ivy Logan.

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MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

Bulletin No. 393 June, 1942

Bay State, A Red Forcing Tomato Bred for Resistance to Leaf Mold

By E. F. Guba

Leaf mold is a devastating disease of tomato in greenhouses and its control is difficult and expensive. This bulletin describes a new greenhouse tomato which combines resistance to certain strains of the fungus with desirable commercial fruit type.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

BAY STATE, A RED FORCING TOMATO BRED FOR RESISTANCE TO LEAF MOLD

By E. F. Guba, Research Professor of Botany

INTRODUCTION

Approximately 1400 tons of greenhouse tomatoes are produced annually in Massachusetts for nearby wholesale markets. About 76 percent or 1070 tons, known locally as the spring crop, are harvested during April to August, inclusive, representing a value of $257,000. The remaining 24 percent or 336 tons, known in contrast as the fall crop, are harvested from September to February and represent a value of approximately $101,400.[1] This production represents a value or gross income to the greenhouse tomato growing industry of about $358,400 annually. It is estimated conservatively that production for the spring and fall crops could be increased by 8 and 30 percent respectively were not the tomato leaf mold disease, caused by the fungus *Cladosporium fulvum* Cke., a deterring factor. This would represent an increase of about 85 tons or $20,400, and 100 tons or $30,100 for the spring and fall cropping seasons respectively, or approximately 185 tons and $50,500 annually. Losses in greenhouse tomato production as the result of this disease occur in the same general proportion all over the world where tomatoes are grown under glass.

Since 1925, the Massachusetts Agricultural Experiment Station has been engaged in a study of the tomato leaf mold disease, and several bulletins and scientific journal articles describing the results of these studies have been issued. Since 1933, all of the effort has been directed toward the study of the reaction of tomatoes to the fungus parasite, and the breeding of a commercially acceptable resistant type. The serious nature of the disease and the inability of growers to control it at reasonable expense and within the limits of usual greenhouse practice have encouraged and justified this long effort.

As a result of this study, a new tomato resistant to certain physiologic forms of this prevalent and devastating fungus has been developed. The tomato has entered commercial production under glass and has proved acceptable to many growers. Therefore, an account of the development and a description of the tomato is now considered desirable.

SOURCE OF RESISTANCE TO CLADOSPORIUM LEAF MOLD

The resistance of the Red Currant tomato to *Cladosporium fulvum* Cke. was first recorded by Sengbusch and Loschakowa-Hasenbusch (10) in 1932 from Germany and confirmed by Guba (6) in Massachusetts and Alexander (1) in Ohio in 1934. This immunity reaction has been reported only for *Lycopersicon pimpinellifolium* (Jusl.) Mill. and derivatives from it. Langford (9) in Ontario found that, although no macroscopic symptoms ordinarily followed inoculation of this species, the fungus penetrated the stomata and developed in the leaf tissue to a very limited extent and in a few instances necrotic non-sporulating infection flecks were produced from which the fungus was readily recovered. Bond (5) in England found no external symptoms on the Red Currant tomato and observed necrotic isolated cells only in immediate contact with the hyphae. On many other Solanaceae classed as immune, the course of infection after penetra-

[1]Compiled from statistics furnished by the Massachusetts Department of Agriculture, Boston.

tion by the fungus was essentially the same; and among other species in other families an extensive mycelium was never developed after penetration, even under favorable conditions. This historical background is offered to call attention to the consistency of reports showing the high degree of resistance of the Red Currant tomato to the Cladosporium fungus, and the definite lack of sporulation even in those rare instances where the fungus was observed to cause a yellowish area about the point of infection.

This new tomato was developed from crosses of *Lycopersicon pimpinellifolium* (Jusl.) Mill. and *L. esculentum* Mill., two distinct species of tomato respectively highly resistant and highly susceptible to tomato leaf mold. Three varieties of esculentum tomatoes—Success, Belmont, and Break O'Day—were selected for the first crosses after a comparative trial of varieties on outdoor trellis in 1933 at Waltham. They are early maturing and bear large red tomatoes. Red color, large fruit, and earliness were considered desirable, since the pimpinellifolium tomato bears red fruits of extremely small size and because only red tomatoes are wanted in the Boston market area.

COMBINING RESISTANCE WITH DESIRABLE COMMERCIAL TYPE

The entire population of the first generation was alike for all plant characters and for resistance to leaf mold. The population of the second generation was resolved into various unlike, desirable and undesirable characters, and resistance and susceptibility to the disease. Selections for desirable characters and for resistance to the disease were continued for two further generations. There appeared to be nothing significant offered by the progenies of one hybrid not also offered by those of the other two; but the fruit, being only ¾ to 1 inch in diameter, was wholly inadequate for size.

The varieties Success, Belmont, and Break O'Day under greenhouse culture show many undesirable characters and, therefore, were considered unsuitable for further crossing with desirable types from the latest generations of the original hybrids. For this purpose, and for a desirable greenhouse forcing type, an improved selection of the Field Station Comet, now known as Waltham Forcing, was employed. A large proportion of the greenhouse tomato production in the Boston area is devoted to Waltham Forcing or similar types. Accordingly, this type was judged to have the qualities most desirable for a greenhouse forcing tomato. The objective then was to develop a type comparable to Waltham Forcing and resistant to leaf mold.

Three successive backcrosses were made with Waltham Forcing, each after selection for three or four generations from disease-resistant and desirable types, and without regard for their original pedigrees. After the third backcrossing the progenies were satisfactory for fruit size and yield, and seed of the second generation of the third backcross was distributed to a few growers for limited trial and selection purposes for the 1939 spring cropping season.

In the fall of 1939, a larger F_3 population was grown in several greenhouses. The performance and the quality of the tomato were unusually promising, but there were also some inherently bad features, notably an hereditary breakdown manifested by yellowing, rusting, spotting, and necrosis of the foliage. Otherwise, about 80 percent of the individuals in these plantings were highly resistant to leaf mold and the foliage remained green and healthy throughout the entire growth from the ground to the tops of the plants, or almost 7 feet. In contrast, the remaining 20 percent of these plants and Waltham Forcing growing in the same greenhouse were "burned up" by the disease. Several growers who met at the greenhouses of Mr. Russell Eisenhaure, Concord, in the fall of 1939, to observe

this leaf mold resistant tomato were greatly impressed by its performance. This demonstration furnished convincing evidence that there could be no mistake in the choice of this tomato where a crop failure or loss from leaf mold was feared or existed. Therefore, it was decided not to wait until the tomato was perfected before distributing more seed samples. This plan made available commercial plantings from which further selections for resistance and desirable commercial types could be made both by the writer and by the growers.

In the interval which has since elapsed, the tomato was made pure for resistance to Cladosporium leaf mold, and was given the name Bay State (7). The tomato has performed in a highly acceptable manner for many growers, and approximately 25–30 percent of the greenhouse area producing tomatoes in the fall cropping season of 1941 in eastern Massachusetts was planted to Bay State.

A loss of two-thirds of the yield of leaf mold susceptible varieties in the fall cropping season is not uncommon. A loss of 17 percent of the yield associated with 45 percent of infected foliage has been recorded for the spring cropping season (8). A comparison of the yields of resistant Bay State and susceptible Kondine, both artificially inoculated with a spore suspension of Cladosporium when 2 feet tall, revealed an increase of 54 percent in favor of Bay State.[2] One Bedford (Massachusetts) grower who had been harvesting 10 to 12 tons of tomatoes of a susceptible variety under devastating attacks of leaf mold in the fall cropping season, reported increases of 2 tons and 6 tons for the fall cropping seasons of 1940 and 1941, respectively, with Bay State. A Concord grower, with a smaller growing area, reported increases of 1½ tons and 2½ tons for the fall cropping seasons of 1940 and 1941, respectively, as the result of substituting the Bay State tomato.

Without destructive occurrences of leaf mold, which is possible particularly in the spring cropping season, Waltham Forcing is definitely superior to Bay State in yield, and under such conditions no encouragement has been given to the culture of the Bay State variety. Where destructive occurrences of the disease have been experienced, or are feared, many growers have chosen and accepted Bay State. The variety is still subject to improvement in the direction of a consistently high yield and more uniformity in plant growth, but these are faults which can be corrected by further selecting. Growers who are planting the Bay State tomato are encouraged to make selections for further growing in their own greenhouses from the most promising and desirable types. Such selections are likely to show better adaptability to local conditions than those from outside sources grown under different and variable conditions.

DESCRIPTION OF BAY STATE TOMATO

This tomato has been grown only in greenhouses to a single or double stem trained to string or cane supports. The botanical characters offered here apply to the variety under that system of culture only.

The Plant

Stem usually 4 feet long when first trusses mature. Growth period (from medium sized plants that have not reached blossoming stage to first harvest in greenhouse) 60–70 days. Habit rather rank, with both leaves and fruiting trusses long and coarse.

[2]By correspondence, Plant Disease Division, Dept. Scientific and Industrial Research, Auckland, New Zealand, February 28, 1941.

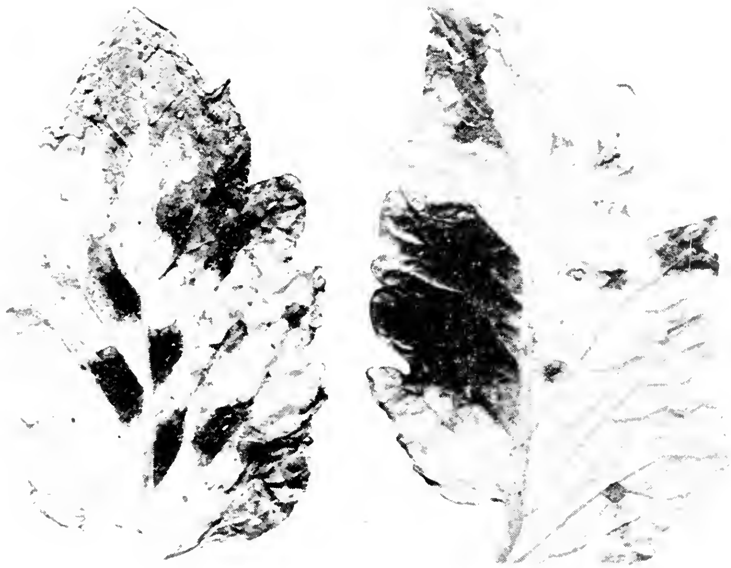

Figure 1

Lower Surfaces of Tomato Leaflets, showing diseased, dead areas overgrown with Cladosporium mold. The entire foliage is ultimately destroyed.

Courtesy, Dr. G. T. Weber.

Figure 2

Inflorescence of the Red Currant Tomato, Lycopersicon pimpinellifolium (Jusl.) Mill., showing racemose and apical furcate habit and mature fruits averaging one half inch in diameter. $\times$ 1/6

Figure 3

Fruit of Bay State Tomato brought to desirable commercial size, contrasted with Red Currant from which resistance to Cladosporium leaf mold was derived. × 1

Figure 4

F_3 Progeny of Original Esculentum × Pimpinellifolium Hybrid, showing segregation for susceptibility (left) and resistance (right). × 1/8

Figure 5

Susceptibility and Resistance to Cladosporium Leaf Mold.

Upper: Waltham Forcing (left), susceptible; Bay State (right), resistant.

Lower: Bay State × Globelle (left), highly resistant; Michigan State (right), highly susceptible.

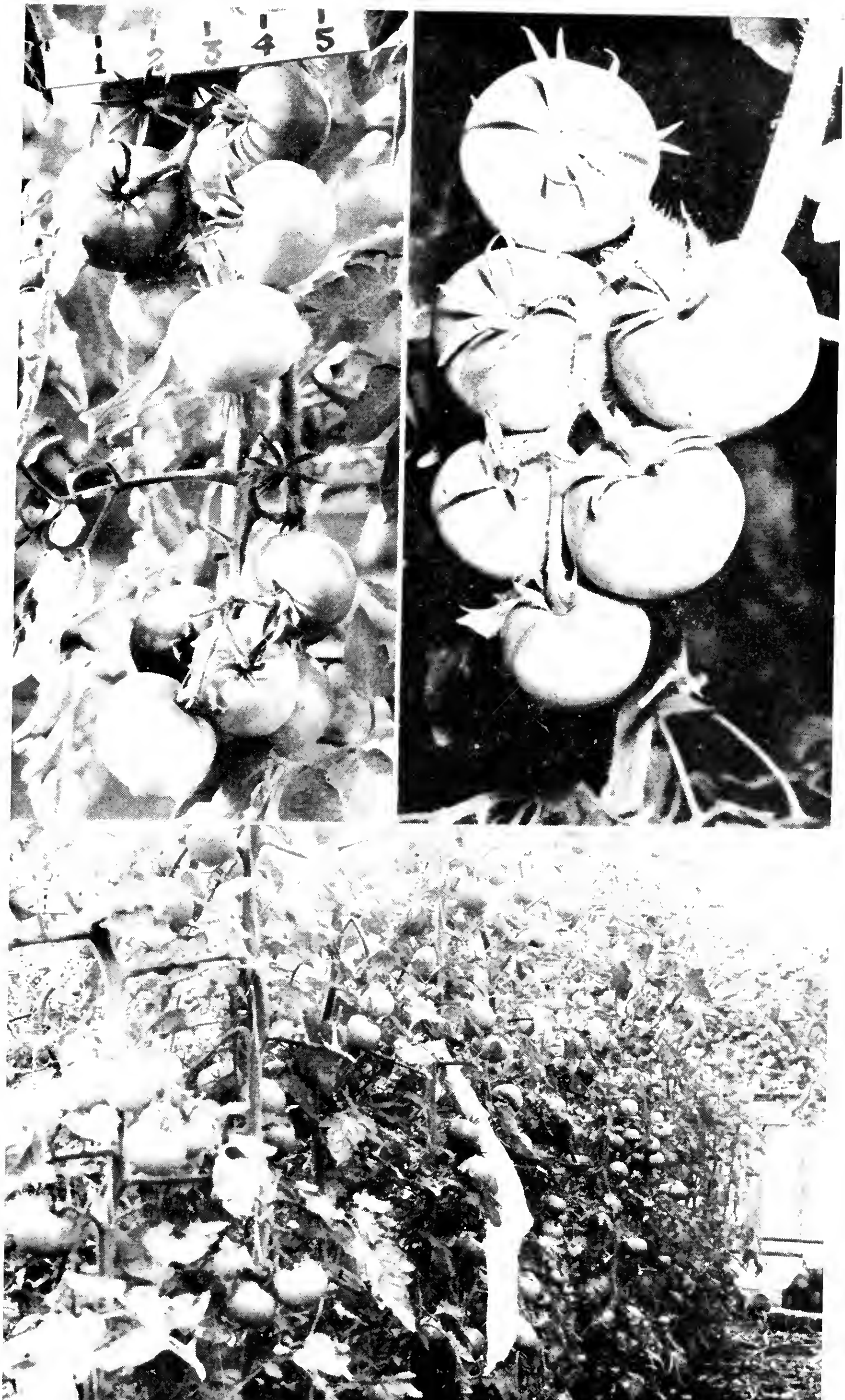

Figure 6. Bay State Tomato.

Upper: Fruiting types in first commercial trial growing, fall cropping season 1939.
Lower: Performance under commercial growing conditions after further selection for desirable fruiting type, August 1940.

Figure 7

Bay State Tomato — fruiting performances under commercial growing conditions, November 1941

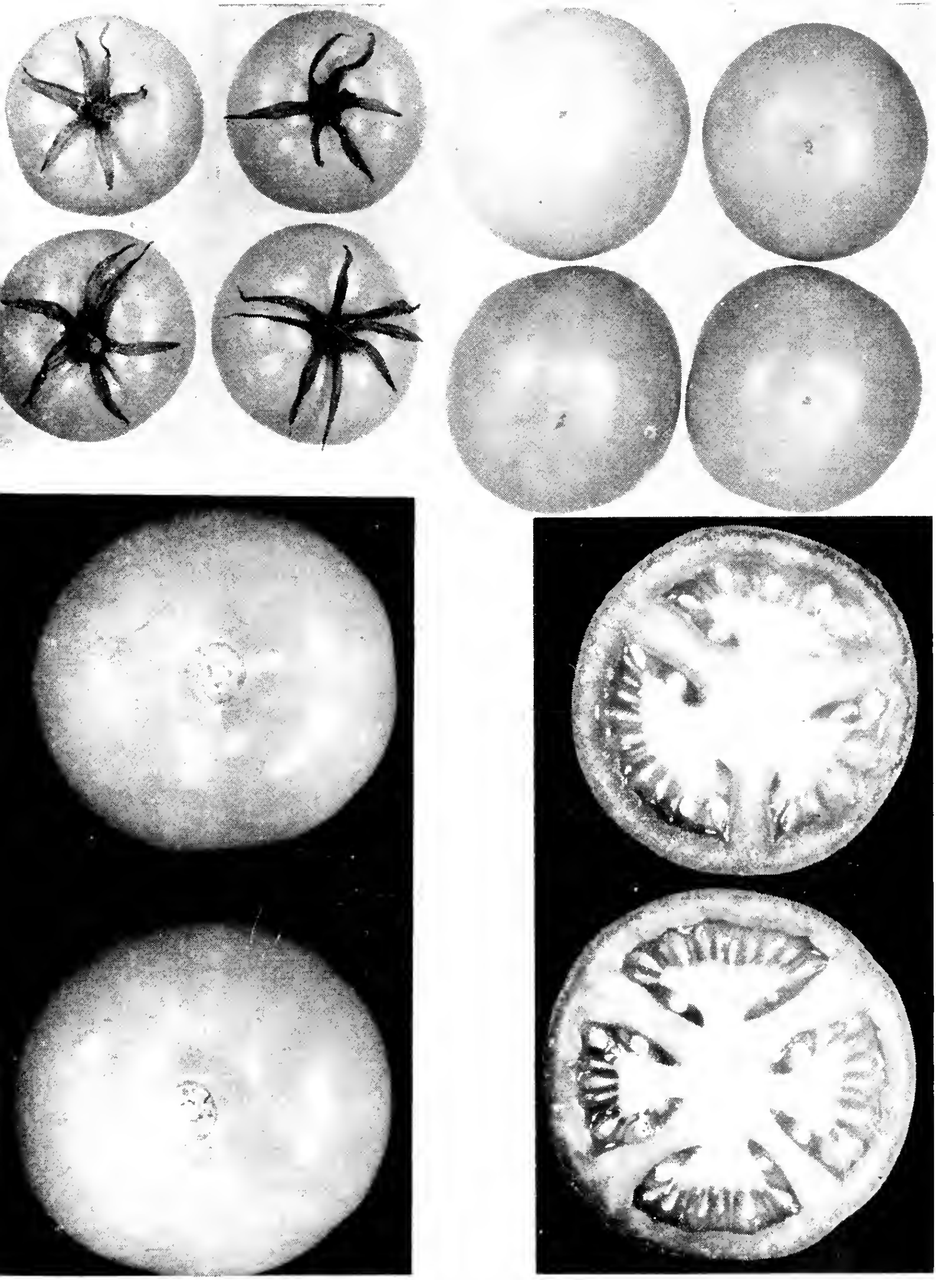

Figure 8

Bay State Tomato Fruits, showing stem and stylar ends (approximately half size), stem end cavity (three fourths size), and cross section showing interior structure.

Figure 9. Bay State Tomato

Upper left: Common, oblong desirable type of fruit.
Upper right: A deeper, occasional type permissible for basket pack and not too seriously objectionable for 5, 6, and 15 pound carton packs.
Center: Six pound carton pack.
Lower: Fifteen pound carton pack.

Foliage

Leaves typically 4–6 inches apart along the stem; under good cultural conditions 17–20 inches long × 15–22 inches wide; upper surface usually dark green, lower surface pale green. Largest leaflets numbering 7–9, coarsely and deeply lobed and irregularly dentate; bladelets 4–6 × 2–3 inches. Medium leaflets 9–13, typically 2½ × 2¼ inches long, slightly lobed, and coarsely and irregularly dentate. Small leaflets usually 8–10, entire, slightly dentate, 1¼–1½ inches long and wide, ovate. Smallest leaflets 7–10, ovate, ½ inch long and wide. Petiolules from 3/16 inch long for smallest leaflets to 3 inches for largest leaflets.

Flower Cluster

Flower cluster racemose, simple or furcate, usually with 6–14 or more flowers; the greater number associated with the furcate racemose habit; developing and maturing usually 4–7 fruits per cluster. Corolla lobes usually 6, and generally ⅜ inch long; calyx lobes or sepals usually 6 or 7, narrow, linear, usually 5/16 inch long. Connivent anthers usually ⅜ inch long, concealing the whole pistil.

Peduncles often 12 inches long, racemose, simple or branched, spreading; declinate, or vertical with the axis or stem in the late fruiting stage from an excessive weight of fruit, and sometimes constricted near the stem therefrom; pedicels 1–1¼ inches long, rarely up to 2 inches.

Fruit Exterior

Sepals

Rather long, 1–1½ inches; ⅛–3/16 inch wide at base, acuminate, frequently 6 or 7, rarely 8, equal and distinct, or 5 distinct and 1 furcate, or 6 distinct with 1 broader than the other 5; straight or slightly curved, erect or divergent, and enveloping the coarse, short pedicel which is about ½ inch long. Sepals and pedicel *light bice green*[3] or of slightly darker or lighter shades.

Immature Fruit

Uniformly *apple green, mineral green, calliste green,* sometimes slightly darker about the stem end.

Mature Fruits

Medium size, firm, weighing 1½–6 ounces, typically 3½–5 ounces each (first grade) and running a high percentage to first grade; oblate or oblong in polar section, round in transverse section, sometimes flattened or oblong when viewed from the side, measuring typically 2¼–2⅝ inches transverse diameter, and 1⅞–2⅛ inches polar diameter, the typical form established before fruit is half grown. Cavity ⅛–¼ inch deep, broad, sloping gradually; side of cavity slightly lobed with 3 or 4, rarely 5, sometimes prominent creases radiating from the corky ring.

Corky scar tissue (stem abscission layer) circular, shallow, concave; corky ring not prominent, usually ⅜–7/16 inch in diameter, stem adhering rather firmly. Stylar end flattened, smooth, usually a slight depression or shallow basin present about stylar scar in ripened fruit. Stylar scar small, 1/16–⅛ inch in diameter, 3 or 4 pointed, not too conspicuous or objectionable, often a mere dot. Streaks radiating from the points of stylar scar but relatively inconspicuous in mature fruit (dark green streaks bordered by pale green in green immature fruit). Flavor mildly subacid

Comparative susceptibility to circumferential and radial cracking not known or observed. Fruit stems snapping off easily at the first node. Color *scarlet* to

[3]Color Standards and Color Nomenclature; Ridgway.

scarlet red, uniform at maturity but progressing toward the stem end; during the ripening process *yellow green* or *chrysolite green* about the stem end and *ochraceous orange* or *ochraceous buff* below, changing to *flame scarlet* and finally to a uniform brilliant *scarlet*. Skin yellow.

Fruit Interior

Outer and inner walls medium thick, typically ¼ inch in thickness and uniform, *light coral red* or *peach red* to *scarlet red*. Coloring of inner walls retarded. Cells 3 or usually 4, regular in shape and arranged as segments of a circle. Central mass well-defined and firm; the core medium, paler, slightly green or retarded in coloring.

Lobes of placentae opposite each other and usually 4, 1 to each cell; cells large, moderately filled with pulp and seed. Seeds medium in numbers per fruit and per unit weight of fruit.

Miscellaneous

In Massachusetts resistant to certain forms of tomato leaf mold caused by the fungus *Cladosporium fulvum* Cke. For commercial market use and considered to be a good shipper and keeper.

ANOTHER FORM OF CLADOSPORIUM LEAF MOLD

In the fall of 1940 a serious attack of leaf mold occurred on the Bay State tomato in a Swansea (Massachusetts) greenhouse. Previously in this place and elsewhere Bay State had been highly resistant.

Earlier in 1940, Alexander[4](3) reported Bay State, Vetomold, Globelle, and Red Currant susceptible to another physiologic form of leaf mold. Vetomold is a red fruiting, leaf mold resistant type originated by Langford (9), and Globelle a pink fruiting resistant type originated by Alexander (1, 2). Both were derived from *L. pimpinellifolium* (Jusl.) Mill. which originally was found to be highly resistant or for all practical purposes immune to the Cladosporium fungus.

Material of the leaf mold from Swansea was used for artificial infection purposes at Waltham. Bay State, Vetomold, Globelle, and Red Currant, which had always been highly resistant in previous performances, were in this test susceptible. On Red Currant, necrotic foliage infection areas were numerous and were covered on the lower surface with a considerable growth of leaf mold. Heretofore, such a phenomenon on Red Currant had not been observed. The progress of the disease was, however, much less serious on Red Currant than on Bay State, Vetomold, and Globelle. The new form of Cladosporium has appeared in other locations in Massachusetts. It is less virulent and destructive on Bay State than the prevalent, normal form of leaf mold on Waltham Forcing and other locally grown varieties.

The disease caused by this new form advances slowly from points of infection, giving rise to yellowish infection flecks between which the normal green color is retained for a time, producing the effect of a checkerboard. Molding and sporulation on the lower surfaces of the leaves is less abundant, or is delayed at least for some time where desirable watering, heating, and ventilating practices are followed. Where excessively damp conditions are encouraged or disregarded, the tomato plants ultimately become seriously affected. The fact that the new form of leaf mold is not now generally prevalent, and seems less virulent than the original form, would appear to render the status of these derivatives of "*pimpinellifolium*" × "*esculentum*" crosses encouraging.

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[4]Correspondence, February 16, 1940.

It is interesting to note here that Langford (9) originally reported four distinct physiologic forms of leaf mold to which Vetomold is resistant. Bay State and Globelle share the same measure of resistance to these forms, since each derived its resistance to the fungus from Red Currant which in widely scattered centers throughout the world has shown a high degree of immunity. The new form to which Vetomold and other derivatives of Red Currant are susceptible is regarded by Bailey and Langford (4) as a fifth physiologic form.

VARIABILITY OF REACTIONS OF LYCOPERSICON TO INFECTION

Alexander (1) recognized five arbitrary classes of resistance: excellent and good grouped together as resistant; and fair, poor, and none grouped together as susceptible. These pathological reactions to infection on various species and varieties of tomatoes were used by Langford in the classification of five strains of the fungus. Cultural studies also have revealed numerous strains of the fungus which produce different pathological reactions.

A completely susceptible type of infection is characterized by a progressive browning and necrosis of the foliage and profuse molding and sporulation when humidity is relatively high. Infected foliage is destroyed progressively and comparatively early. Under relatively dry conditions, the progress of infection is characterized by slowly expanding brown necrotic spots with only a limited amount or no sporulation on the lower surface. Reactions within this range are found on Ailsa Craig, Potentate, Waltham Forcing, Kondine, Comet, Michigan State.

In contrast, a partial resistance or less virulent type of infection is manifested on other varieties. Infections are restricted to a smaller area and they are conspicuously yellow on the upper surface. Both necrosis and sporulation occur eventually but to a comparatively slight degree, and they are restricted to the center of the spots. The surrounding yellow areas are more conspicuous above than below. In a continued moist atmosphere the final reaction may be comparable to complete susceptibility, but under conditions of relatively low humidity there is little or no sporulation. This type of infection is shown by Norduke, Maincrop, Up-to-Date, Stirling Castle, Bay State, Vetomold, Globelle.

A similar reaction expressing a still greater degree of resistance or extreme resistance is manifested by progressively enlarging yellowish infection areas. The centers ultimately become necrotic and sporulation occurs in and from the centers only in a moist atmosphere. This resistance is manifested by *Lycopersicon hirsutum* Humb. and Bonpl. and *L. pimpinellifolium* (Jusl.) Mill.

Immunity or complete resistance to the fungus is offered by *L. peruvianum* (L.) Mill. The macroscopic symptoms of infection are of an expanding yellowish type, indefinitely outlined, extremely rare, and non-sporulating. This type of reaction was originally exemplified by Red Currant, *L. pimpinellifolium* (Jusl.) Mill., to all of the known forms of *Cladosporium fulvum* Cke. Attempts to hybridize *L. peruvianum* and *L. esculentum* have failed completely. Pollination of "esculentum" flowers with pollen from *L. peruvianum* gives rise to tomato fruits of good size but no seed is ever produced.

Langford (9) described a kind of partial resistance manifested by progressively enlarging, necrotic, non-sporulating infection areas developing under high atmospheric moisture conditions and resembling symptoms following inoculation with the common virulent strain of the fungus on susceptible varieties under conditions of relatively low humidity.

Confirmation of the identity of the several reported strains of *Cladosporium fulvum* Cke. is desirable. In view of the difficulty and uncertainty of providing and maintaining at Waltham pure culture atmospheres for infection purposes,

a study of strains or physiologic forms of the fungus was not undertaken. It is evident, however, that in addition to pathological reactions manifested by Lycopersicon, cutaneous responses of persons allergic to the fungus should also be extremely useful in differentiating physiologic forms.

SUMMARY

Bay State, a new tomato for greenhouse forcing, is described and illustrated. It was developed for resistance to Cladosporium leaf mold from crosses of *Lycopersicon pimpinellifolium* (Jusl.) Mill. and *L. esculentum* Mill., respectively highly resistant and highly susceptible.

The new tomato was released for commercial trial in 1939, and approximately one-fourth of the greenhouse tomato area in Massachusetts was planted to this variety in the fall cropping season of 1941.

In the fall cropping season of 1940, however, the Bay State tomato growing in a greenhouse in Swansea, Bristol County, experienced a severe attack of leaf mold, caused by a new physiologic form of Cladosporium. In the fall of 1941 other instances of the susceptibility of Bay State to the new physiologic form of the fungus were observed. The Globelle and Vetomold varieties of tomato, likewise developed for resistance to *Cladosporium fulvum* Cke. and derived from *L. pimpinellifolium*, have shared the same experience in Massachusetts and elsewhere.

The new physiologic form of the fungus is infectious to *L. pimpinellifolium*, causing yellowish infection flecks and ultimately necrosis. On the lower leaf surface of the necrotic areas and under moist atmospheric conditions, the fungus grows and sporulates rather freely. This form of the fungus is considered to be less virulent on the Bay State tomato than the normal devastating physiologic form on Waltham Forcing; and with some degree of proper greenhouse management should yield more readily to control.

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The Control of Damping-off of Vegetables by Formaldehyde and Other Chemicals

By W. L. Doran, E. F. Guba,

and C. J. Gilgut

Damping-off is one of the most serious problems of the vegetable grower, and the results here reported should provide safer and more effective control of the disease in hotbeds and greenhouses.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

THE CONTROL OF DAMPING-OFF OF VEGETABLES BY FORMALDEHYDE AND OTHER CHEMICALS

By W. L. Doran and E. F. Guba, Research Professors, and C. J. Gilgut, Research Assistant, in Botany

CONTENTS

The original object of this work was to determine the relative merits of certain chemicals for the control of damping-off of vegetables in hotbeds and cold frames. There has been a gradual change in practice, however, and most vegetable growers in Massachusetts now start plants in plant houses or greenhouses. The control of damping-off as here considered is, therefore, not limited to hotbeds and cold frames, but conclusions are unaffected. Whether in greenhouses or under glass elsewhere, at least 90 percent of the damping-off of vegetables in this State is caused by *Pythium* spp., with Rhizoctonia important on cabbage and other crucifers and *Aphanomyces euteiches* Drechsler often the pathogen in the case of celery.

It is, of course, a common practice to treat seeds of vegetables with red cuprous oxide, Semesan, or zinc oxide. These seed treatments give good results with some vegetables; but with other vegetables, seed treatment is inferior to certain soil treatments for the control of post-emergence damping-off.

Damping-off, as is well known, may also be severe in steamed soil, especially if the soil is exposed to reinfestation by fungi before seeding.

There is need of a safe and effective chemical treatment which can be applied to soil shortly before germination, that is, immediately after seeds are sowed and covered with soil; and special but not exclusive attention is here given to that phase of the problem. Some chemicals have been thus used in a limited way by a few earlier investigators, and that work is referred to below, but such results have not as yet had much effect on the practice of growers.

Some of the chemicals here used can be and are recommended to growers. Others are mentioned because they are apparently good substitutes for a possibly more effective material if or when the latter is temporarily unavailable. Still others are discussed briefly because they show sufficient merit to warrant further investigation.

Grouped by families, the vegetables with which most of this work was done are as follows: Chenopodiaceae or goosefoot family — beet, spinach, and Swiss chard; Compositae or composite family — chicory, dandelion, endive (escarole), and lettuce; Cruciferae or mustard family — broccoli, Brussels sprouts, cabbage, cauliflower, collards, cress, water cress, kale, and kohlrabi; Cucurbitaceae or gourd family — cucumber, muskmelon, and summer squash; Liliaceae or lily family — onion; Solanaceae or nightshade family — eggplant, pepper, and tomato; Umbelliferae or parsley family — celery and celeriac; Leguminosae or pulse family — pea.

Results are usually expressed in terms of stand or number of plants which lived, escaping damping-off. Most of the experiments were repeated and each

figure in most of the tables (e. g., Table 10) represents the average of the results in several experiments. Such a tabulation can hardly bring out all the facts which would be evident if each experiment were reported upon separately; but they were thus brought together to save space, and conclusions are in each case stated in the text.

TREATMENTS OF SEEDS

Spergon[1] was used only for the treatment of the seeds of Lima bean and gave very good results. The number of plants which lived was increased 76 percent by it, only 21 percent by red cuprous oxide or zinc oxide, and some injury was caused by Semesan.

Treatments of seeds of vegetables with red cuprous oxide, Semesan, and zinc oxide were, in many experiments, compared with one another and with certain treatments of the soil. The results, averages for each of the treatments investigated, are recorded in Table 10.

[1]A product of the United States Rubber Company.

TABLE 1.—RECOMMENDED SEED TREATMENTS FOR VEGETABLES

Beet	Semesan or red cuprous oxide
Broccoli	Semesan or zinc oxide
Brussels sprouts	Zinc oxide or Semesan
Cabbage	Semesan or zinc oxide
Carrot	Red cuprous oxide or zinc oxide
Cauliflower	Semesan or zinc oxide
Celery and celeriac	Zinc oxide
Chicory	Semesan or zinc oxide
Collards	Semesan or zinc oxide
Corn	Semesan
Cress, water	Red cuprous oxide
Cucumber	Semesan or red cuprous oxide
Dandelion	Red cuprous oxide or Semesan
Eggplant	Semesan or zinc oxide
Endive	Semesan or zinc oxide
Kale	Semesan or zinc oxide
Kohlrabi	Semesan or zinc oxide
Lettuce	Red cuprous oxide or Semesan
Muskmelon	Red cuprous oxide or Semesan
Onion	Semesan
Parsnip	Zinc oxide
Pea	Semesan
Pepper	Semesan or red cuprous oxide
Radish	Semesan or zinc oxide
Spinach	Red cuprous oxide or Semesan
Squash, summer	Semesan or red cuprous oxide
Swiss chard	Semesan or red cuprous oxide
Tomato	Zinc oxide or red cuprous oxide
Turnip	Semesan or zinc oxide

Table 1, based on that work and on other observations, especially as regards safety or freedom from chemical injury, consists of a list of vegetables together with the materials which, when used for the treatment of their seeds, resulted in the least damping-off and the best stands of each. Some show a decided preference for one chemical, e.g., celery and parsnip for zinc oxide. In the case of other vegetables, differences between results with two chemicals were not great enough to prove that there are preferences.

Treatments of seeds of beet, spinach, Swiss chard, tomato, endive, lettuce, cucumber, summer squash, and muskmelon usually gave results inferior to those secured by formaldehyde treatment of the soil; either method satisfactorily protected pepper, celery, and chicory; and seed treatments often gave better results than formaldehyde treatment of the soil with eggplant, onion, dandelion, and especially crucifers.

Treatment of the seeds of such vegetables is important, especially where there is a scarcity of seeds, where seeds are sown in the field, or where soil disinfestation is not feasible. As far as possible, growers will do well to keep in stock all of the chemicals named in Table 1 and to follow the recommendations which are therein made.

TREATMENTS OF SOILS

Chlorpicrin Emulsions

Chlorpicrin is sometimes injected into soil for the prevention of damping-off but, because of the danger of injury to plants, such applications must be made long before seeding. As used here, Larvacide chlorpicrin emulsion[2] and Seidorin chlorpicrin emulsion[3] were applied to soil (0.64 to 1.0 cc. in 0.8 quart water per square foot) immediately after seeding. Seidorin, 1 cc. per square foot, gave good results with beet, cabbage, lettuce, pea, pepper, and spinach (see Table 2). Damping-off of these vegetables, and of broccoli and cucumber, was also well controlled by Larvacide chlorpicrin emulsion similarly used. Thus applied, immediately after seeding, best results were generally obtained, however, by the use of Larvacide chlorpicrin emulsion 0.64 cc. or Seidorin chlorpicrin emulsion 0.76 cc. per square foot, greater concentrations or heavier applications being often injurious.

When applied at the rate of 1 gallon to 30 feet of row after sowing seeds of pea but before covering them, Larvacide chlorpicrin emulsion 1:1000 markedly improved the stands (see Table 9), giving as good results, in fact, as did formaldehyde.

Used in these ways, chlorpicrin emulsions are certainly effective against damping-off. But, on grounds of convenience and practicability, they are not preferred by the writers for the control of this disease. It is difficult to secure uniform dilutions and, hence, to make uniform applications; and the fumes of chlorpicrin are, moreover, decidedly unpleasant.

Acetic Acid and Vinegar

Acetic acid, worked into soil before seeding, has been successfully used for the control of damping-off (4)[4].

Applied to the surface of soil after seeding, glacial acetic acid, 1.5 to 2.5 cc. in 0.8 quart water per square foot, gave good results with lettuce, pepper, spinach, beet, chicory, dandelion, endive, cabbage, and cauliflower (see Tables 2 and 10).

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[2]From Innis Speiden and Co. It contains 70 percent chlorpicrin.
[3]From Japan Seed Co. It contains 45 percent chlorpicrin.
[4]Numbers in parentheses refer to literature cited, page 20.

TABLE 2.—RELATIVE NUMBER OF PLANTS WHICH LIVED IN SOIL TREATED IMMEDIATELY AFTER SEEDING

Soil Treatment[1]	Beet	Cabbage	Cauliflower	Celery	Eggplant	Lettuce	Pea	Pepper	Radish	Spinach	Tomato
No treatment (check)	100	100	100	100	100	100	100	100	100	100	100
Formaldehyde 2 cc.	133	109	83	135	108	338	295	123	101	341	102
Acetic acid 2 cc.	111	...	109	106	102	136	116	124	97	214	101
Seidorin 1 cc.	118	163	108	62	95	269	295	135	88	275	101
Chlorox 30 cc.	91	103	100	90	89	227	101	50	85	145	106
Copper zeolite[2] 5.67 gm.	113	76	79	109	92	175	106	108	...	...	...
Vasco[3] 5.67 gm.	110	95	100	97	103	147	106	121	101	89	82
Cuprocide 54[4] 5.67 gm.	106	86	84	91	94	220	164	123	88	93	98
Semesan 5.67 gm.	...	...	...	...	55	...	...	...	97	44	96
Bordeaux 1.5:1.5:50	...	94	...	...	98	135	117	118	100	72	92

[1]In 0.8 quart of water per square foot.
[2]Containing 25 percent copper.
[3]A zinc compound for seed treatment, made by Virginia Smelting Co.
[4]A red cuprous oxide, product of Rohm and Haas.

Thus used, it often gave results which were somewhat inferior to those obtained by formaldehyde; but, lacking the latter, acetic acid or vinegar is a good substitute.

Vinegar as commonly sold contains 4 to 5 percent acetic acid Damping-off was usually well controlled, and without injury to most plants with which it was used, when vinegar (a little less than one-half pint per square foot) was worked into soil before seeding (4).

Vinegar, 215 cc. (0.45 pint) in 1 quart water per square foot, completely prevented damping-off when applied to soil immediately after seeding. Thus used, it increased by the following percentages the number of plants which lived: beet, 427; cucumber, 112; cabbage, 56; lettuce, 24; and pepper, 106. Applied without additional water, this quantity of vinegar interfered with the growth of cabbage but did not affect beet and cucumber.

When applied from below, by setting pots or flats of soil in the solutions until soil was saturated, vinegar 1.5 quarts in 1 gallon water or acetic acid 1:55 gave good results, although not so good as did formaldehyde.

The soils with which vinegar was used in the experiments referred to above had pH values of about 5.8. In one case, vinegar (215 cc. in 1 quart water per

TABLE 3.—EFFECT OF SOIL REACTION ON VINEGAR AS A SOIL DISINFESTANT

Soil Treatments	Soil pH Values	Relative Number of Plants Which Lived		Percentages Which Damped-off	
		Beet	Cucumber	Beet	Cucumber
None (check)	5.8	100	100	18	84
Vinegar	5.8	435	725	0	0
None (check)	7.1	100	100	16	45
Vinegar	7.1	137	148	7	8

square foot) was applied, immediately before seeding, to a soil having a pH value of 5.8 and to the same soil after its pH value had, by the earlier use of hydrated lime, been changed to 7.1. There was no injury to growth of beet or cucumber and vinegar was effective in both soils; but, as may be seen by reference to Table 3, it was considerably more effective in improving stands in the acid soil than it was in the soil with a high pH value.

Copper, Mercury, and Zinc Compounds

Red cuprous oxide 1 pound or yellow cuprous oxide 12 ounces in 50 gallons water is sometimes used (13, 14) as a seedbed spray, applied first when seedlings emerge and later at weekly intervals although, for better results, such treatment should be supplemented by treatment of seeds. Earlier investigators (15), reporting good results after spraying with red cuprous oxide, obtained better control with Bordeaux mixture 2:1:50, 1 quart per square foot, two applications at intervals of 3 days, beginning upon the first appearance of damping-off.

But Bordeaux mixture is sometimes injurious (13), seedlings of crucifers are susceptible to injury by red cuprous oxide used in this way, and, in the work of the writers, neither Bordeaux mixture nor a spray of red cuprous oxide controlled damping-off as well as did seed treatments. Nor did these copper sprays, including copper zeolite, control damping-off as well as did treatment of soil with formaldehyde (see Table 2).

Cuprocide, 0.2 ounce in 0.8 quart water per square foot, gave good results only with lettuce, pepper, and pea, not with the other eight vegetables with which it was used; and stands of all of them except cauliflower were more improved or less injured by formaldehyde.

Bordeaux mixture was also of some benefit to lettuce, pea, and pepper, but stands were more improved by formaldehyde and even by red cuprous oxide.

When red cuprous oxide was dusted on to seedbeds, first (at the rate of 0.9 gm. per square foot) as seedlings emerged and again (at the rate of 2.9 gm. per square foot) a week later, cabbage was injured but stands of lettuce seedlings were improved. In another experiment, however, stands of lettuce and celery were more improved by seed treatment with red cuprous oxide than they were by that treatment supplemented by soil treatment with red cuprous oxide.

Semesan, 1 ounce in 3 gallons water (1 to 1.5 quarts for 10 square feet), has been advocated as a supplement to seed treatment with Semesan. A much heavier application, as used on seedbeds, was somewhat injurious and certainly of no benefit to tomato, eggplant, radish, and spinach (see Table 2).

Dusted on to a lettuce seedbed immediately after the seeds were covered and again a week later, Semesan, Calochlor, Corona P. D. 7, and corrosive sublimate were injurious. Thus used, calomel (0.47 and 1.8 gm. per square foot for the first and second applications, respectively) caused no injury and improved the stands, but red cuprous oxide (0.85 and 2.95 gm. per square foot) gave better results. These materials were all somewhat injurious to cabbage.

Blackleg and black rot of some crucifers have been controlled, although not without some chemical injury, by a solution of corrosive sublimate, 1:1000, applied three times to the seedbed (2); and dilutions of 1:1280 or 1:1600, applied directly to plants in the seedbed, have controlled Rhizoctonia wire stem (8, 9). These results have been the basis for recommending the application of corrosive sublimate solutions to cabbage and cauliflower seedbeds at weekly intervals beginning when seedlings emerge, using 1 ounce to 10 gallons for cabbage and 1 ounce to 15 gallons for cauliflower. But this method is not widely used for the control of damping-off. Preference is more generally given and, it seems, with

good reason, to seed treatment with Semesan or zinc oxide and to soil disinfestation by other chemicals or by steam.

The use of corrosive sublimate on soil immediately after seeds of crucifers are sown is, in any case, no guarantee of good stands. A solution, 1:1000, sometimes gave good results with Brussels sprouts, but the number of seedlings of collards and kohlrabi which lived was increased more by seed treatment with Semesan than by soil treatment with corrosive sublimate.

Zinc oxide 0.5 ounce per square foot, applied as a dust to the surface of seedbeds immediately after seeds are covered, has been recommended more as a supplement to seed treatment than as a substitute for it (13). But zinc oxide so used by other investigators was not very effective (15), and as used here with lettuce was of no benefit.

In another case, zinc oxide and Vasco, a zinc compound, were twice dusted upon seedbeds, once immediately after the seeds were covered and again a week later. This did not improve stands of lettuce at all, but it did improve stands of cabbage more than did copper–lime dust.

Zinc oxide, 0.2 ounce in 0.8 quart water per square foot of soil, improved the stands of lettuce and pepper less than did other treatments similarly applied immediately after seeding; and Vasco thus used with the vegetables named in Table 2 was not of significant benefit to any except lettuce and pepper. Zinc oxide applied in water tends to cause the surface of the soil to cake and become hard, and on the basis of results obtained by the writers, it is not recommended for use in this manner.

Useful as red cuprous oxide, Semesan, and zinc oxide are for the treatment of seeds of some vegetables, it does not appear that there is much to be said for them as soil disinfestants for the control of damping-off. Then too, when applied in water they settle out of suspension unless continually agitated. This makes uniformity of application difficult and probably accounts for some of the injury on the one hand and some of the failures to control on the other.

Sodium Hypochlorite

Chlorox and Oxol, each containing 5.25 percent sodium hypochlorite, did not in most cases give as good results as other treatments of soil or seed. That is in line with the results of Horsfall (13) in whose work Chlorox caused some injury and failed to control damping-off satisfactorily.

Stands of pepper seedlings were much less improved by Oxol (38cc. in 0.8 quart water per square foot) than by formaldehyde. As may be seen by reference to Table 2, Chlorox did not significantly improve the stands of nine out of the eleven kinds of vegetables named. It did improve stands of lettuce and spinach but not so much as did formaldehyde or Seidorin or, in the case of spinach, acetic acid.

In controlling damping-off, solutions of Chlorox thus applied to soil were no better than standard dry treatments of seeds of pepper and endive, and decidedly less effective than standard dry treatments of seeds of beet, chicory, cabbage, cauliflower, eggplant, and tomato.

Salicylic Acid

Salicylic acid can be used as a soil fungicide. When worked, without water, into soil immediately before seeding, it usually increased the number of plants which lived and there was no injury to beet or cucumber by applications up to 10 gm. per square foot (4). Damping-off was well controlled (See Table 4) by 5 or 6 gm. salicylic acid thus applied to soil immediately before seeding. There was some injury to cress but not to beet or pepper.

TABLE 4.—EFFECT OF SALICYLIC ACID ON CONTROL OF DAMPING-OFF

Salicylic Acid[1]	Relative Number of Plants Which Lived			Percentages Which Damped-off	
	Beet	Cress	Pepper	Beet	Cress
None (check)	100	100	100	16	13
5.0 gm. per square foot	410	157	136	3	0
6.0 gm. per square foot	416	157	165	0	0
7.5 gm. per square foot	521	...	...	0	..

[1]In 1 quart of water.

Formic Acid

Formic acid is sufficiently effective as a soil fungicide to warrant further investigation, but it is not safe enough to be recommended to growers until more is learned about how to use it. When a dust containing 9 cc. formic acid (in 38 gm. powdered charcoal) per square foot was well worked into soil immediately before seeding, lettuce and beet were uninjured and the number of seedlings which lived was increased 98 percent in the case of beet and 117 percent in the case of lettuce. Formic acid 9 cc. (in 1 quart water) per square foot, applied immediately before seeding, improved the stands of lettuce but caused some injury to cabbage and cucumber.

Pyroligneous Acid

Except for a temporarily retarding effect on early growth of cauliflower, pyroligneous acid, 155 cc. per square foot, gave good results with several vegetables. Worked into soil immediately before seeding, the undiluted acid improved the stand of beets 367 percent and of lettuce 135 percent. Applied to soil (in 1 quart water per square foot) immediately after seeding, it improved the stand of tomato by 149 percent, of cauliflower by 100 percent, and of lettuce by 98 percent.

Oxyquinoline Sulfate

Oxyquinoline sulfate is known to have fungicidal properties (6, 7). Applied in solutions (1.25 quarts water per square foot) immediately after seeding, 2 gm. per square foot was safe with all vegetables with which it was used, except cabbage. Damping-off was well controlled by this application and the number of plants which lived was increased as follows: beet, 120 percent; cabbage, 62 percent; cucumber, 107 percent; lettuce, 34 percent; and pea, 53 percent. Beet and cucumber seedlings damped-off to the extent of 43 and 21 percent in untreated soil. In treated soil, these figures fell to 3 and 2 percent, respectively. Oxyquinoline sulfate is, it is evident, effective as a soil fungicide.

Calcium Cyanamide

Damping-off is controllable by calcium cyanamide, 10 to 12 gm. per square foot, but it is unsafe to sow seeds until at least 2 weeks after soil treatment (4). This is, however, a good material to use if, for any reason, soil must be treated long before seeding and then exposed to recontamination; for soil treated with it is not so promptly reinfested with damping-off fungi as is soil treated with formaldehyde. When calcium cyanamide, 12 gm. per square foot, was worked into soil

30 days before seeding, the number of plants which lived was increased as follows: beet by 176 percent, cabbage by 18 percent, cucumber by 450 percent, and lettuce by 55 percent. It should be noted, as a basis of comparison with these results, that damping-off was more severe in soil treated with formaldehyde (2 cc. per square foot) 30 days before seeding than it was in untreated soil, for the treated soil had, by that time, become heavily reinfested with soil fungi. Such treatment with formaldehyde applied to soil before seeding gave good protection for about 5 days, some protection for about 11 days, but practically no protection if seeds were sowed 11 days or more after soil treatment.

Ammonium Hydroxide and Ammonium Sulfate

Ammonium hydroxide and ammonium sulfate reduced losses caused by a root-rot of sugar beet if applied to soils having sufficiently high pH values (3); and ammonium sulfate, with lime, has been successfully used in the protection of cotton against a root-rot (16).

Ammonium hydroxide was applied to a soil having pH values of 6.0 or 7.1, the latter value resulting from the earlier use of hydrated lime. Seeds were sowed 10 days after the application of ammonium hydroxide, with the results shown in Table 5.

TABLE 5.—EFFECTS OF AMMONIUM HYDROXIDE AND SOIL REACTION ON THE CONTROL OF DAMPING-OFF

Ammonium Hydroxide[1]	Relative Number of Plants Which Lived					Percentages Which Damped-off		
	Beet	Cabbage	Cress	Cucumber	Pepper	Beet	Cress	Cucumber
pH Value of Soil Before Treatment, 6.0								
None (check)	100	100	100	100	100	40	17	66
10 cc	227	140	157	120	128	8	0	7
16 cc.........	268	187	155	225	140	0	0	0
20 cc.........	240	160	150	214	125	0	0	0
pH Value of Soil Before Treatment, 7.1								
None (check)	100	100	100	100	100	21	18	18
10 cc.........	237	163	182	158	128	0	0	0
16 cc.........	260	139	156	172	145	0	0	0
20 cc.........	218	133	158	209	153	0	0	0

[1]In 1 quart of water per square foot.

The only injury to growth was caused by 20 cc. and that was confined to cress and cucumber in the soil with a pH value of 7.1. Ammonium hydroxide thus used controlled damping-off practically as well and improved stands practically as much in a soil which, before treatment, had a pH value of 6.0 as it did in a soil which had a pH value of 7.1, although control of damping-off by the lightest application, 10 cc., was slightly less good in the acid soil.

In another experiment (see Table 6), ammonium hydroxide, 12 cc. (in 1 quart water) per square foot, gave good results in soil with a pH value of 7.1, even when seeds of beet were sowed immediately after soil treatment; but for best results with 16 cc., it was necessary to wait a few days before seeding.

TABLE 6.—EFFECT OF AMMONIUM HYDROXIDE, AND INTERVAL BETWEEN SOIL TREATMENT AND SUBSEQUENT SEEDING, ON STAND OF BEET SEEDLINGS

Time Interval Between Soil Treatment and Seeding	Relative Number of Plants Which Lived		
	Untreated Soil (check)	Ammonium Hydroxide 12cc.	Ammonium Hydroxide 16cc.
0 days	100	250	87
3 days	100	332	134
5 days	100	158	127
7 days	100	132	167
10 days	100	189	228
12 days	100	160	224
14 days	100	253	306

There was a strong odor of ammonia when ammonium sulfate was worked into a relatively moist soil which had previously been limed. Ammonium sulfate, 8, 10, or 12 gm. per square foot, thus applied to soil 24 hours before seeding, gave good results in soil with an initial pH value of 7.0 but had little or no effect on damping-off in soil with an initial pH value of 5.9 (see Table 7). Growth of cucumber and cress, but not of beet and lettuce, was, in this case, somewhat retarded by 12 gm., not by the lighter applications.

TABLE 7.—RESULTS WITH AMMONIUM SULFATE IN SOIL OF THE DIFFERENT pH VALUES NAMED

Ammonium Sulfate	Beet		Cress		Cucumber		Lettuce	
	pH 7.0	pH 5.9	pH 7.0	pH 5.9	pH 7.0	pH 5.9	pH 7.0	pH 5.9
Relative Number of Plants Which Lived								
None (check)	200	100	284	100	316	100	185	100
8 gm. per square foot	325	138	258	110	300	132	197	100
10 gm. per square foot	413	124	267	137	375	147	196	109
12 gm. per square foot	229	...	267	...	284	...	190	...
Percentages Which Damped-off								
None (check)	29	46	42	72	17	66	18	25
8 gm. per square foot	5	33	0	33	1	15	5	17
10 gm. per square foot	2	43	0	51	0	22	3	12
12 gm. per square foot	0	..	0	..	0	..	0	..

In other experiments, a mixture of one part (by weight) of ammonium sulfate and two parts of hydrated lime was prepared. Both were dry and there was practically no trace of the odor of ammonia. The mixture was stored in tightly stoppered glass containers and, after 1 week, worked into soil at such a rate that each square foot of soil received 10 gm. ammonium sulfate and 20 gm. hydrated lime. There was a strong odor of ammonia when this mixture was applied to slightly moist soil. This treatment, applied immediately before seeding, slightly retarded the growth of all species and interfered with the germination of seeds of cabbage, eggplant, and tomato; but it lessened the severity of damping-off

and improved the stand of beet, 52 percent; of cress, 70 percent; and of cucumber, 175 percent.

In another case, lime and ammonium sulfate were similarly applied to soil together and seeds were not sowed until 24 hours later Here again, growth of all species was somewhat retarded, but all damping-off was prevented and the number of plants which lived was increased as follows: beet by 42 percent, cabbage by 29 percent, cress by 45 percent, cucumber by 34 percent, and lettuce by 100 percent

In still another case, seeds were not sowed until 2 and 5 days after soil was treated. Even then, growth of all species was a little retarded in soil into which ammonium sulfate (10 gm.) and lime (20 gm.), together, had been well worked, but damping-off was well controlled and the number of plants which lived was considerably increased (seeTable 8). For complete safety it is evidently necessary to wait more than 5 days after such treatment of soil before seeding.

TABLE 8.—RESULTS WITH AMMONIUM SULFATE AND HYDRATED LIME APPLIED TOGETHER TO SOIL, TWO AND FIVE DAYS BEFORE SEEDING

Treatment	Interval Between Treatment and Seeding (Days)	Relative Number of Plants Which Lived			Percentages Which Damped-off		
		Beet	Cress	Cucumber	Beet	Cress	Cucumber
No treatment (check)		100	100	100	25	20	54
Lime only		125	140	166	6	4	19
Ammonium sulfate and lime	2	342	177	257	0	0	0
Ammonium sulfate and lime	5	200	...	286	0	..	0

Formaldehyde

Formaldehyde has long been used as a soil disinfestant but much is still being learned about better, more convenient, or more economical ways to use it in controlling damping-off. Examples are the formaldehyde dust method (1, 20) and the use of relatively light applications before seeding (10, 11). Neither of these methods is, however, wholly safe in the confined air and sometimes cold soil of sash-covered frames, and both methods make use of more formaldehyde than is really needed for the control of damping-off. Using 0.75 or 0.8 quart of the solution per square foot of soil, Haensler (12) controlled damping-off of beet with 3.5 cc. formaldehyde per square foot; and Ogilvie et al. (17) were able to improve the emergence of pea seedlings by 3.75 cc. to 1.25 cc. formaldehyde per square foot.

Formaldehyde, 2 cc. per square foot, gave good results with pea when used as described in Table 2. Onion smut has long been controlled by dripping formaldehyde into the drills with the seeds (19), and it has been similarly and successfully used with pea (13) and with spinach (18). Formaldehyde solutions (1 gallon to 30 feet of row) and formaldehyde dust were applied in the rows after seeds of pea were sowed in the field but before they were covered. There was no injury by any treatment and there was an improvement of about 40 percent in stands following treatment with a 1:400 solution (see Table 9). That was true also of formaldehyde dust but seed treatments gave even better results.

In the experiments the results of which are summarized in Table 10, formaldehyde 1.25 to 3.8 cc. (in 0.8 quart water) per square foot was applied to soil immediately after seeding.

TABLE 9.—RESULTS OF APPLYING SOIL DISINFESTANTS TO PEA SEED IN THE ROW AT TIME OF PLANTING

Treatment	Relative Number of Plants Which Lived
Soil Treatments	
Liquid Treatments[1]	
Water only (check)	100
Acetic Acid 1:300	113
Formaldehyde 1:200	136
1:300	134
1:400	140
Larvacide 1:500	136
1:700	129
1:1000	141
Dry Treatments	
No treatment (check)	100
Formaldehyde, 6-percent dust, 0.25 pound to 30 feet of row	138
0.33 pound to 30 feet of row	141
Seed Treatments	
Semesan	213
Red cuprous oxide	203

[1]Liquids were applied at the rate of 1 gallon to 30 feet of row.

Stands of beet, spinach, Swiss chard, and onion were improved by an application of 1.5 to 2.5 cc.; those of eggplant, tomato, pepper, celery, and celeriac by 2.0 or 2.5 cc. per square foot; and 1.5 or 2.0 cc. was effective with chicory, dandelion, endive, and lettuce. Lettuce is more likely to be injured by formaldehyde than are beet and spinach but it is less susceptible to such injury than are the crucifers.

Stands of cabbage and Brussels sprouts were sometimes improved by formaldehyde 1.25 to 2.0 cc., those of kohlrabi by 1.5 cc. per square foot; but formaldehyde did not give good results with collards, cauliflower, and water cress. Crucifers are more susceptible to injury by formaldehyde (also by acetic acid, salicylic acid, pyroligneous acid, and oxyquinoline sulfate) than are most other vegetables; and it is safer to protect crucifers by seed treatment with Semesan or zinc oxide than by soil treatment with formaldehyde.

Cucurbits, on the other hand, are relatively tolerant of formaldehyde, and stands of summer squash, cucumber, and muskmelon were much improved by formaldehyde, 1.5 or 2.0 cc. per square foot.

Table 11, based on these and other experiments, contains suggested rates of application for most of the vegetables other than crucifers, 1 fluid ounce (2 tablespoonfuls) of formaldehyde in 2.5 to 3.5 gallons water being enough to cover 12 to 17 square feet of seedbed.

Rates of application suggested in Table 11 are based rather more on what is safe with different vegetables than on what is required to kill the fungi which cause damping-off. They are to be considered more as maximum rates of application than as absolute minima; although, in heavily infested soil, it would not be wise to go far below them.

TABLE 10.—RELATIVE NUMBERS OF PLANTS WHICH LIVED AFTER CERTAIN TREATMENTS OF SOIL OR SEED

Treatment		Beet	Swiss chard	Spinach	Chicory	Dandelion	Endive	Lettuce	Broccoli	Brussels sprouts	Cabbage	Cauliflower	Collards	Garden cress	Kale	Kohlrabi	Cucumber	Muskmelon	Summer squash	Onion	Eggplant	Pepper	Tomato	Celery
No treatment (check)		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Soil Treatments[1]																								
Formaldehyde	1.25 cc.	...	...	...	...	...	297	197	...	117	117	114	...	94	102	111	...	...	...	...	...	...	...	...
	1.5 cc.	307	217	140	176	300	142	232	110	135	133	133	72	120	...	108	488	874	...	140	...	111	146	104
	2.0 cc.	246	211	359	165	219	174	221	107	140	125	102	82	117	73	99	478	758	170	141	115	115	131	121
	2.5 cc	283	238	339	145	...	114	117	...	...	68	72	...	...	...	...	521	760	168	151	119	104	139	149
	3.8 cc.	136	...	167	...	...	...	...	...	...	...	...	...	...	...	...	128	...	...	120	82	121	143	145
Acetic acid	1.25 cc.	...	...	...	...	...	347	133	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	1.5 cc.	81	...	...	128	300	164	163	111	...	89	90	...	...	...	...	78	...	...	83	...	...	...	...
	2.0 cc	271	...	220	137	375	162	136	100	...	111	118	...	...	...	...	131	310	...	95	109	110	98	100
	2.5 cc	301	...	273	126	125	105	99	102	...	126	121	...	...	...	...	...	...	...	106	77	120	124	...
	3.8 cc.	120	...	101	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	70	114	125	128	65
Larvacide	0.64 cc.	210	...	509	134	100	108	111	161	...	241	122	...	...	...	...	227	...	...	138	...	...	...	...
	0.76 cc.	158	...	233	144	350	117	127	120	...	245	119	...	...	...	...	133	...	...	121	...	120	107	150
	1.00 cc.	121	...	...	...	...	130	...	...	...	79	54	...	...	...	...	...	...	...	100	...	...	...	62
Seidorin	0.76 cc.	312	...	...	181	...	154	153	144	...	...	187	...	...	...	...	235	...	...	173	...	...	...	...
	1.00 cc.	187	...	362	120	...	105	136	152	...	226	120	...	...	...	...	200	...	...	129	96	129	100	105
Seed Treatments																								
Red cuprous oxide		273	165	362	150	454	154	365	107	131	141	123	101	182	105	106	375	652	140	109	143	133	121	98
Semesan		228	219	263	160	400	114	432	130	152	210	139	139	226	166	122	406	688	167	176	134	119	112	92
Zinc oxide		149	95	197	139	225	155	167	124	128	162	139	92	131	141	105	228	459	123	...	138	119	105	202

[1]In 0.8 quart of water per square foot of soil, applied after seeding.

TABLE 11.—SUGGESTED RATES OF APPLICATION OF FORMALDEHYDE IMMEDIATELY AFTER SEEDING, FOR THE CONTROL OF DAMPING-OFF OF VEGETABLES

Vegetable	Formaldehyde (In 0.8 Quart Water per Square Foot)*
Beet	2.5 cc.
Celery and celeriac	2.0 cc.
Chicory	1.75 cc.
Cucumber	2.0 cc.
Dandelion	1.75 cc.
Eggplant	2.5 cc.
Endive	1.75 cc.
Lettuce	1.75 cc.
Muskmelon	2.0 cc.
Onion	2.0 cc.
Pepper	2.0 cc.
Spinach	2.5 cc.
Squash, summer	2.0 cc.
Swiss chard	2.5 cc.
Tomato	2.0 cc.

*2.5 cc. formaldehyde thus applied = 1 fluid ounce in 2.5 gallons of water on 12 square feet of seedbed; 2.0 cc. formaldehyde = 1 fluid ounce in 3 gallons of water on 15 square feet; and 1.75 cc. formaldehyde = 1 fluid ounce in 3.5 gallons of water on 17 square feet.

Formaldehyde, properly diluted, may be applied to soil immediately after sowing seeds of some vegetables without determining the exact rate of application of the solution. Damping-off of a number of species was well and safely controlled by 1 teaspoonful (4.9 cc.) formaldehyde in 1 gallon water (1 tablespoonful in 3 gallons) when soil, after seeding, was watered with it without determining the exact quantity of the solution applied per square foot (5). It is likely, however, to be 1.5 pints to 1.5 quarts of the solution, or about 0.9 to 1.8 cc. formaldehyde per square foot, and, at least with some vegetables, the exact quantity of water applied is not very important. As may be seen by reference to Table 12, damping-off was well controlled by formaldehyde, 2 cc. per square foot, applied immediately after seeding, whether 0.75, 1.25, or 1.75 quarts of the solution was applied per square foot. The soil was moderately dry and there was some injury to cress but not to cucumber, lettuce, and pea.

TABLE 12.—CONTROL OF DAMPING-OFF BY FORMALDEHYDE, 2 CC. PER SQUARE FOOT, APPLIED IN DIFFERENT QUANTITIES OF WATER

Treatment	Relative Number of Plants Which Lived				Percentages Which Damped-off		
(Per Square Foot)	Cress	Cucumber	Lettuce	Pea	Cress	Cucumber	Beet
Check (water 1.25 quart)	100	100	100	100	31	31	14
Formaldehyde, 2 cc.							
In 0.75 quart water	123	211	139	320	0	0	0
In 1.25 quart water	215	156	118	397	0	0	3
In 1.75 quart water	174	178	153	236	0	0	0

TABLE 13.—RESULTS WITH DIFFERENT CONCENTRATIONS OF FORMALDEHYDE, THE RATE OF APPLICATION PER SQUARE FOOT OF SOIL BEING UNDETERMINED

Treatment	Relative Number of Plants Which Lived					
	Beet	Cabbage	Cress	Cucumber	Pepper	Tomato
Check (water only).........	100	100	100	100	100	100
Formaldehyde—teaspoonfuls in each gallon of water						
1.0......................	275	141	142	247	118	146
1.5......................	332	50	47	189	...	142
2.0......................	288	0	13	216	120	134

Thus used, the concentration of formaldehyde known but the rate of application (immediately after seeding) not accurately determined, 0.5 teaspoonful in 1 gallon water did not give complete protection against damping-off but 1 teaspoonful did, and the latter improved the stands (see Table 13) as much as did greater concentrations. Crucifers were injured by 1.5 teaspoonfuls formaldehyde per gallon, but 2 teaspoonfuls did not injure beet, cucumber, pepper, and tomato.

When a solution containing 1 teaspoonful formaldehyde in each gallon of water is applied to soil at the rate of 1 quart per square foot, each square foot receives 1.2 cc. formaldehyde. This is probably safe with all vegetables, unless it be the crucifers; but some of the non-crucifers will stand, and may well receive, somewhat heavier applications. Up to 2 quarts of the solution (2.4 cc. formaldehyde) per square foot did no harm to beet, cucumber, pepper, and tomato.

With the object of determining the lightest applications of formaldehyde which are or may be effective against damping-off when applied to soil immediately after seeding, it was so used in the quantities named in Table 14.

TABLE 14.—RESULTS OF SOIL TREATMENTS WITH FORMALDEHYDE IN LIGHT APPLICATIONS

Formaldehyde (Per Square Foot)	Relative Number of Plants Which Lived					Percentages Which Damped-off		
	Beet	Cress	Cucumber	Eggplant	Lettuce	Beet	Cucumber	Lettuce
None (check)	100	100	100	100	100	26	62	43
0.2 cc........	29	118	47	100	105	47	67	33
0.4 cc........	223	144	510	114	120	8	12	7
0.6 cc........	237	173	612	130	132	3	0	4
0.8 cc........	325	163	703	132	120	3	0	0
1.0 cc........	330	156	800	140	138	2	2	0
1.2 cc........	272	...	827	...	125	0	0	0
1.4 cc........	247	...	812	...	132	0	0	0
1.6 cc........	294	...	714	...	146	0	0	0
1.8 cc........	276	...	829	...	140	0	0	0
2.0 cc........	330	...	743	133	139	0	0	0
3.0 cc........	247	...	845	...	131	0	0	0

There was no control by formaldehyde, 0.2 cc. per square foot, but there was fair control by 0.4 cc., good control by 0.6 cc., and very good control by 1.2 cc. per square foot, the last named giving quite as good results as did heavier applica-

tions. It is evident that very light applications may be effective, but even 1.5 to 2.5 cc. are light applications compared with those commonly used in the past. Growers should follow the suggestions made in Table 11 unless formaldehyde is difficult to obtain in the amount desired. In that case, lighter applications, down to about 1.0 cc. per square foot, may be made with the expectation that, even if damping-off is not eliminated, at least its severity will be materially reduced.

The application of formaldehyde after seeding is an effective and, except with crucifers, a safe method of preventing damping-off. It is also convenient, for water must usually be applied at this time anyway. There are, however, a few simple precautions to be remembered. Soil so treated should not be covered, as with burlap, or the formaldehyde fumes may be held in the soil long enough and in sufficient concentration to injure seeds. Seeds should not be soaked in water before planting, for soaking makes them more susceptible to injury by formaldehyde used in this way. Very cold water, water at a temperature below 50° F., ought not to be used in preparing the solutions of formaldehyde. A colder soil delays both germination and the release of formaldehyde fumes. Formaldehyde in very cold water kills damping-off fungi but, for the reasons above stated, it is more dangerous to seeds.

It should be understood, of course, that only soil treatment with formaldehyde *or* seed treatment, not both, is to be used.

Soil reaction does not appear to have an important effect on the efficacy of formaldehyde used in this way. When formaldehyde (2 cc. in 1 quart water per square foot) was applied to soil the pH value of which had been earlier adjusted with hydrated lime, damping-off of beet, cucumber, and lettuce was equally well controlled in soils having pH values of 5.5, 5.9, 6.1, and 7.0.

It is interesting to note in this connection that, although soil acidity is not a sufficiently important factor affecting damping-off to make the disease ordinarily controllable by the adjustment of soil reaction (4, 15), damping-off was usually less severe in limed than in unlimed soil. Each line, horizontally in Table 15 represents a separate experiment. Soils without lime had pH values of 5.9 to 6.1. The same soils after treatment with hydrated lime had pH values of 7.0 to 7.2. Damping-off was by no means entirely prevented by liming, but the average number of plants which lived was greater in limed soils than in unlimed soils by 51 percent in the case of beet, 163 percent in the case of cress, and 258 percent in the case of cucumber.

TABLE 15.—STANDS AND DAMPING-OFF AS AFFECTED BY LIMING OF SOIL

Relative Number of Plants Which Lived						Percentages Which Damped-off					
Beet		Cress		Cucumber		Beet		Cress		Cucumber	
Lime	No Lime	Lime	No Lime	Lime	No Lime	Lime	No Lime	Lime	No Lime	Lime	No Lime
200	100	284	100	366	100	29	46	42	73	17	60
127	100	109	100	352	100	10	10	18	17	18	62
125	100	150	100	186	100	6	25	0	20	29	50
100	100	125	100	170	100	8	7	4	12	33	56
204	100	151	100	217	100	3	10	5	5	0	6

As is well known, the application of formaldehyde to soil, in quantities sufficient to be fungicidal but not injurious, often results in improved growth of plants. That was true in many of the experiments referred to above. With the object of determining whether or not formaldehyde also improves growth if applied to

soil already freed of soil fungi, formaldehyde was applied immediately after seeding, to previously untreated soil and to soil which had been steamed five days earlier.

As may be seen in Table 16, formaldehyde improved the growth of all vegetables in soil not previously treated and, except with lettuce, steaming had a similar effect. But in no case did formaldehyde applied to steamed soil improve the growth of plants as compared with their growth in soil which was steamed and received no formaldehyde. It seems probable that the stimulatory effect of formaldehyde is due principally or wholly to its freeing the plants of the retarding effect of soil fungi. It is noteworthy, too, that formaldehyde when applied to steamed soil often interfered with growth although it had quite the opposite effect on soil not steamed. There is not much likelihood of formaldehyde's being applied to soil recently steamed; but if, for any reason, it is, the results may apparently be unfortunate.

TABLE 16.—EFFECT OF FORMALDEHYDE, IN STEAMED AND UNSTEAMED SOIL, ON GREEN WEIGHT OF PLANTS

Soil Treatment	Average Green Weight per Plant, Expressed as Relative Numbers							
	Formaldehyde Diluted 1.25 Teaspoonfuls per Gallon				Formaldehyde Diluted 1 Teaspoonful per Gallon			
	Beet	Cress	Cucumber	Pea	Beet	Cress	Cucumber	Lettuce
None (check)	100	100	100	100	100	100	100	100
Formaldehyde only	118	108	110	166	117	237	133	114
Steam only	141	125	124	162	115	269	135	51
Formaldehyde and steam	141	25	60	160	80	50	83	42

To learn how many times it is safe to water with very dilute formaldehyde (4.9 cc., one teaspoonful, in 2 gallons water) after seeding, and to learn how this controls damping-off, soil was treated at the time of seeding and again once or twice more at intervals of 2 days. Results are recorded in Table 17.

TABLE 17.—EFFECT OF DILUTE FORMALDEHYDE APPLIED TO SOIL MORE THAN ONCE AFTER SEEDING

Number of Treatments with Formaldehyde[1]	Relative Number of Plants Which Lived			Percentages Which Damped-off			Relative Green Weight per Plant		
	Beet	Cress	Cucumber	Beet	Cress	Cucumber	Beet	Cress	Cucumber
None (check)	100	100	100	30	11	12	100	100	100
One	323	233	131	0	2	0	121	143	141
Two	326	158	124	0	1	0	135	114	105
Three	292	141	122	0	3	0	114	86	74

[1]One teaspoonful in 2 gallons water.

Three applications did not injure growth of beet (nor, in another experiment, growth of pepper) but three applications retarded the growth of cucumber and cress seedlings. Growth of all was improved or unaffected by two applications, but the number of plants which lived was, in all cases, increased as much by one application as by more. It is of interest to note that, although 0.5 teaspoonful formaldehyde per gallon (and about 1 quart of the solution per square foot) gave

good protection, it failed in this experiment as in earlier ones, to increase stands as much as did 1 teaspoonful formaldehyde per gallon similarly applied.

It is sometimes desirable to water soil from below as, for example, after sowing small seeds which might be buried or washed out if soil were watered from above in the usual way. If soil does not already contain too much water, formaldehyde may be effectively applied at the same time and from below.

Immediately after seeding, formaldehyde was applied by subirrigation to a relatively dry and sandy soil (about 4 inches deep) in flats and pots, by setting them into shallow pans of the solution until the soil was saturated. Damping-off in soil which received only water killed 50 percent of the beet, 28 percent of the lettuce, and 37 percent of the cucumber seedlings. There was no chemical injury to these vegetables and all damping-off was prevented by formaldehyde, 3 teaspoonfuls per gallon of water. This treatment increased the number of plants which lived by 176 percent in the case of beet, 100 percent in the case of lettuce, and more than 400 percent in the case of cucumber. Formaldehyde 2 teaspoonfuls per gallon may be enough, for, thus used only with beet, it greatly reduced the severity of damping-off and increased by 225 percent the numbers of seedlings which lived.

In the experiments represented in Table 18, a dry soil was brought to several different percentages of saturation with water before treatment with formaldehyde (3 teaspoonfuls per gallon), applied from below after sowing seeds of beet. This treatment was effective if soil before treatment was no more than 25 percent saturated, but it was ineffective if soil before treatment was already 50 percent saturated.

TABLE 18.—EFFECT OF SOIL MOISTURE ON CONTROL OF DAMPING-OFF OF BEET BY FORMALDEHYDE APPLIED FROM BELOW

Soil Moisture Before Treatment	Treatment	Relative Number of Plants Which Lived	Percentages Which Damped-off
....	Water only(check)	100	54
Saturated	Formaldehyde[1]	500	50
50% Saturated	Formaldehyde[1]	840	31
25% Saturated	Formaldehyde[1]	1233	0
Air Dry	Formaldehyde[1]	1075	0

[1] 3 teaspoonfuls per gallon of water.

Formaldehyde solutions were, immediately after seeding, also applied by subirrigation to relatively dry soil in metal flats[5] so made, with double bottoms, that soil can be watered from below. The volume of soil was small, only about 2 inches deep, and the application of the solution, equal to more than 1.5 quarts per square foot of soil surface, was heavy. Under these conditions, 1 teaspoonful formaldehyde per gallon gave good and best results, increasing the number of plants which lived by 31 percent in the case of lettuce, 130 percent with cabbage, and 85 percent with tomato. More than 1 teaspoonful formaldehyde per gallon injured cabbage and lettuce but not tomato.

It should be noted that in all the experiments mentioned in this bulletin, soil *after* treatment was watered from above, not below. In the few experiments in which the comparison was made, formaldehyde, acetic acid, vinegar, and salicylic acid were less safe if, after fungicidal treatment, soil was watered from below.

[5] Waterite seed flats.

SUMMARY

There is no one best standard dry chemical treatment for the seeds of all vegetables. Red cuprous oxide is to be preferred for some, Semesan for others, and zinc oxide for still others. A list of vegetables (Table 1) together with the seed treatments which most improved the stand of each is included in this bulletin.

Applied to soil after seeding, chlorpicrin emulsions controlled damping-off very well but, because of their too unpleasant fumes and the instability of the emulsions, they are not preferred by the writers for this purpose.

Damping-off was more effectively controlled by vinegar in an acid soil than in one with a high pH value. Acetic acid and vinegar are good substitutes for formaldehyde but they did not, in general, and as applied to soil after seeding, give results equal to those obtained by formaldehyde.

Spraying seedbeds and seedlings with Bordeaux mixture, red cuprous oxide, or zinc oxide proved to be less effective and satisfactory in controlling damping-off than soil treatments with formaldehyde or certain seed treatments. Applied to soil after seeding, mercury compounds were often injurious to crucifers and, even at best, results were no better than those which followed seed treatments.

Substances containing sodium hypochlorite gave results inferior to those secured by formaldehyde, acetic acid, and chlorpicrin emulsions.

Salicylic acid, pyroligneous acid, and oxyquinoline sulfate gave good results with the vegetables with which they were used and they could be substituted for formaldehyde in controlling damping-off of these vegetables.

Formic acid gave results which justify its further investigation but not, for the present, its recommendation.

For the control of damping-off calcium cyanamide has its uses, more especially if, for any reason, soil must be treated long before seeding.

Ammonium hydroxide, applied before seeding to soil of an initial high pH value, controlled damping-off very well, and treated soil did not become promptly reinfested. Ammonium sulfate was effective in a soil with a high pH value but it had little protective effect in a too acid soil. Damping-off was prevented by ammonium sulfate and hydrated lime applied together, but seeds or plants may be injured unless seeding is deferred until more than 5 days after soil treatment.

Stands of pea were much improved by formaldehyde applied in the rows at the time of seeding.

Formaldehyde solutions, from 1 pint to about 1 quart water per square foot, usually gave excellent results when applied to soil immediately after seeding. Very light applications, down to about 0.6 cc. formaldehyde per square foot, were fairly effective, but suggested rates of application of formaldehyde (see Table 11) vary from about 1.75 cc. per square foot for more easily injured seeds such as those of lettuce and other composites to 2.5 cc. per square foot for less readily injured seeds such as those of beet and spinach. In practice, this means that 1 fluid ounce of formaldehyde is enough for 12 to 17 square feet of seedbed. A less discriminating method but one effective and safe with the few vegetables, except crucifers, with which it was used consists in applying a solution of formaldehyde, 1 teaspoonful in 1 gallon of water, immediately after seeding without determining the exact rate of application of the solution.

Repeated applications of very dilute formaldehyde, after seeding, interfered with growth in some cases and gave no better results than one application

Formaldehyde gave good results when applied to soil from below, by subirrigation, provided that the soil did not already contain too much water

Growth of plants was usually improved by formaldehyde applied to soil not previously sterilized, but this was not the case when it was applied to soil which had been recently steamed.

Applied to soil before seeding, formaldehyde, as used, gave good protection against damping-off for about 5 days after soil treatment; little or no protection after 11 days.

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Preparation and Use of Artificial Manures

By Karol J. Kucinski

The real or assumed dependence of crop production upon animal manures has encouraged this attempt to provide an artificial substitute.

MASSACHUSETTS STATE COLLEGE
AMHERST, MASS.

Illustrating the use of a snow fence in building neat-appearing, circular, artificial manure piles. A similar homemade fence can be constructed using 4 foot wooden laths nailed 2 to 3 inches apart to two wires.

PREPARATION AND USE OF ARTIFICIAL MANURES

By Karol J. Kucinski,[1] Research Assistant in Agronomy

Introduction

The Soil's Need for Manure

In the economy of nature, the most productive soils are those rich in organic matter or humus. Land which has been farmed for many years is apt to be seriously deficient in organic matter.

The incorporation of organic matter into the soil is beneficial in several ways. It improves sandy soils by acting as a binder and increases their water-holding capacity; loosens and lightens heavy loams and makes them easier to work; serves as an important source of plant food; improves biological conditions of the soil; checks leaching of plant food and erosion of soil; and helps in many other less tangible ways. Manure has long been used as a source of organic matter for soil improvement.

In England, experiments at Rothamsted Experimental Station, covering from seventy to eighty years, showed that when commercial fertilizers replaced organic manures soil deterioration was eventually observed. Organic manures, on the other hand, maintained production at a higher and more uniform level over this long period, and practically no soil depletion was evident.

These facts are of prime importance in gardening and in special intensive cropping systems in which definite rotations with green manures cannot be, or are not, employed. Unfortunately, natural manure has one drawback — there has never been enough of it. This scarcity has perhaps been one of the reasons for the use of non-organic chemical fertilizers.

The rapid replacement of horses by steam- and gas-driven machines on farms and in cities during the last twenty-five years has made the problem of obtaining natural manure more difficult. When it is realized that each year of farming tends to decrease the organic matter already in the soil; that comparatively fewer animals, especially horses, are kept on the farm to supply organic material by way of manure; and that more intensive cultivation is required to supply the needs of an ever-increasing population, the seriousness of the organic-matter problem is easily seen.

The Possibilities of Artificial Manures

It was to meet these conditions that work was started on the production of artificial manures. England was one of the first countries to feel the scarcity of barnyard manure, and it was at Rothamsted in 1919 that the process of preparing artificial manure chemically was first developed.

The biological principle underlying the preparation of artificial manure is quite simple. The process of natural decay of organic material rich in carbonaceous compounds such as cellulose, lignin, starches, and sugars can be greatly speeded up by the addition of readily available nitrogen and some phosphorus compounds. In other words, the microorganisms which are the true agents of decay need a balanced food ration in order to continue their activities and increase in numbers. In any plant material the ratios of carbon to nitrogen and carbon to phosphorus are very wide. The addition of available nitrogen and

[1]Acknowledgment is made to A. B. Beaumont and W. S. Eisenmenger, who helped in outlining the project and assisted in the work by their interest and many helpful suggestions.

phosphorus compounds narrows the ratios and establishes more favorable conditions for rapid growth of the microorganisms responsible for the process of decay. In the making of artificial manures, the addition of nitrogen and phosphorus to the organic materials is most essential. Potassium is generally added to make the chemical composition of the finished artificial manure more comparable to that of the natural manure. Today anybody can make excellent manure out of almost any kind of plant refuse by following simple directions.

Experimental

These experiments with artificial manure are supplementary to a series run previously at this Station, but not published. The earlier experiment dealt with the preparation of manure from various kinds of organic matter. Very small lots of manure were prepared, and vegetation tests showed some signs of toxicity due probably to the reagents used. In these small lots of manure, the temperature did not rise during preparation as it does when larger masses are made.

In the present experiments, larger quantities of manure were prepared from different types of organic materials, in order to study the method of preparation, rate of decomposition, heat and moisture relationships, and volume and appearance of the finished product. Detailed chemical and vegetation tests were run on the prepared manures to compare the different organic materials and the different nitrogenous supplements used.

Method Used for the Preparation of Artificial Manure

Chopped corn stover, mixed deciduous leaves, and oat straw were the organic materials used, in lots of one half ton on the dry basis for each pile. Two nitrogenous supplements, used to aid decomposition of the organic matter, were compared — Cyanamid (supplied by the American Cyanamid Company) and ammonium sulfate. Enough limestone was added to the piles built with ammonium sulfate to equal the calcium in the piles made with Cyanamid. The nitrogenous supplements were used in sufficient quantity to supply 0.7 percent nitrogen, based on the dry weight of the original organic material. Other supplements added to make the finished product approach natural manure in chemical composition were the following: 16 percent superphosphate, at the same rate as the ammonium sulfate; muriate of potash, at one third the rate of the superphosphate; fresh horse manure, 100 pounds per ton of dry organic material; and garden soil, at the same rate as the manure. The garden soil and horse manure were added as bacteriological inoculating agents.

In building the stacks, a circular snow fence[2] bin about nine feet in diameter was used as a form. The snow fence was taken down and used over again each time a new pile was built. The piles were made indoors on ground covered with tarred roofing paper, and were built up in layers consisting of about six inches of compacted organic material. The chemical reagents were sprinkled on, layer by layer; and each layer was also sprinkled with water as it was being packed down. Enough water was used to wet the material, but not enough to leach out at the bottom of the pile. A half ton of dry organic material was about 350 cubic feet in volume and made an initial circular stack about nine feet in diameter and six feet high. A thermometer was placed in the center of each heap, enclosed within an iron pipe so that the thermometer could be pulled up by a string to take the readings.

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[2]The snow fence was similar to those used along roads by the Highway Department for the prevention of snow drifting during the winter. The fence can be made of 4-foot wooden laths (like those used in plastering), nailed 2 to 3 inches apart to two wires, thus making the fence flexible and easily rolled up.

The heating within the piles commenced almost at once, and the heaps had to be reforked and sprinkled with water to lower their temperature. During the entire time of decomposition the heaps were either sprinkled with water or reforked when the temperature rose to the vicinity of 65° Centigrade (149° Fahrenheit). The rates of decomposition of the different organic materials were not the same, thus making it necessary to water or refork the heaps on different dates, but the total number of waterings and reforkings was the same for each heap. The temperature readings taken in the center of each heap are shown graphically in figure 1. It is to be noted that the temperatures of the manures differed greatly only with the types of organic material and differed only very slightly with the different chemical treatments. Higher temperatures were obtained for a longer time with the corn stover. The piles made from leaves were very slow in heating and never attained the high temperatures of the corn stover or straw piles.

Water was added as needed to keep the mass saturated but below the point of excessive leaching. The sprinkling of the straw and leaf heaps had to be performed with care, for these materials had a tendency to shed water at first. After each sprinkling the temperature made a decided drop and then came up again within a day or two, but never to the previous high temperature reading.

The leaves decomposed much more slowly than the corn stover or straw. The corn stover piles were the first to take on the appearance of rotted manure, while the piles from leaves took twice as long before they began to appear decomposed. It was this slow rate of decomposition of the heaps made from leaves that prevented the use of this manure in the vegetation tests.

At the end of 135 days the temperature in the centers of the heaps made from straw and corn became constant and equal to the outside air temperature, which

TABLE I. — PLANT NUTRIENTS IN ORGANIC MATERIALS USED IN MAKING ARTIFICIAL MANURE AND IN THE FINISHED PRODUCT — MOIST BASIS

Material	Weight Pounds	Moisture Percent	Nitrogen Percent	Phosphoric Acid (P_2O_5) Percent	Potash (K_2O) Percent	Calcium Oxide (CaO) Percent	Magnesium Oxide (MgO) Percent	Total Insoluble Matter Percent
Analysis of Organic Materials								
Corn stover......	1,702	41.2	.49	.22	1.02	.49	.32	2.15
Oat straw	1,185	15.6	1.00	.26	2.03	.63	.52	1.60
Mixed leaves.....	1,513	33.9	.60	.17	.13	1.28	.31	3.60
Analysis of the Artificial Manures								
Corn Stover with								
Ammonium sulfate	2,965	80.8	.36	.30	.48			
Cyanamid.......	3,033	78.3	.43	.37	.55			
Oat straw with								
Ammonium sulfate	2,880	81.2	.42	.30	.52			
Cyanamid.......	2,723	80.4	.51	.31	.49			
Leaves with								
Ammonium sulfate	2,671	72.8	.50	.33	.31	1.55	.46	4.48
Cyanamid.......	2,513	71.2	.50	.45	.35	2.18	52	5 03
Leaves and garbage								
With Cyanamid		71.5	.88	1.18	.91	1.19	.30	6.40

The author was assisted by the Control Service in making these analyses.

Table 2. — Plant Nutrients in Organic Materials Used in Making Artificial Manure and in the Finished Product — Oven Dry Basis

Material	Weight Pounds	Dry Matter Pounds	Dry Matter Percent	Oven-dry Basis — Percent: Nitrogen	Phosphoric Acid (P_2O_5)	Potash (K_2O)	Calcium Oxide (CaO)	Magnesium Oxide (MgO)	Total Insoluble Matter
Analysis of Organic Materials									
Corn stover	1,702	1,000	58.8	.83	.37	1.74	.83	.54	3.65
Oat straw	1,185	1,000	84.4	1.19	.31	2.40	.75	.62	1.90
Leaves	1,513	1,000	66.1	.90	.25	.20	1.93	.47	5.44
Analysis of the Artificial Manures									
Corn stover with									
Ammonium sulfate, $(NH_4)_2SO_4$	2,965	569	19.2	1.85	1.58	2.50			
Cyanamid, $CaCN_2$	3,033	658	21.7	1.96	1.68	2.52			
Oat straw with									
Ammonium sulfate	2,880	541	18.8	2.21	1.62	2.75			
Cyanamid	2,723	534	19.6	2.58	1.59	2.51			
Leaves with									
Ammonium sulfate	2,671	727	27.2	1.80	1.20	1.15	5.68	1 68	16.45
Cyanamid	2,513	724	28.8	1.72	1.56	1.20	7.56	1.79	17.47
Leaves and garbage									
With Cyanamid		.....	28.5	3.08	4.14	3.20	4.16	1.02	22.45

The author was assisted by the Control Service in making these analyses.

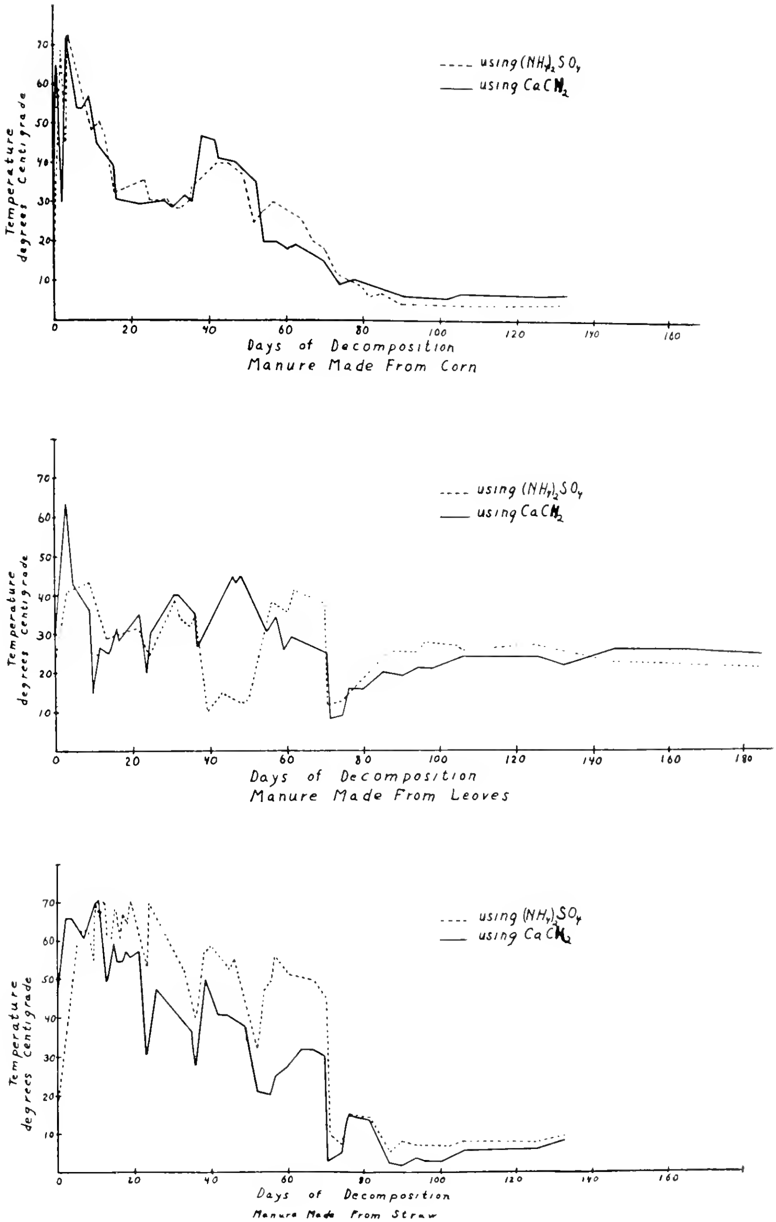

Figure 1. Temperatures During Period of Decomposition. Taken at center of manure heaps made of different organic materials.

showed the end of rapid decomposition. The finished product, which looked like well-rotted manure, was weighed and samples were taken for moisture and chemical analyses. The manure from leaves was weighed and sampled at the end of 170 days. Tables 1 and 2 show the chemical composition of the different manures, both on the "oven-dried" basis and on the wet-manure basis, also the chemical composition of the organic materials before any chemicals were added or decomposition started. It will be noted that the manure made from straw contained much more nitrogen than the manure made from corn stover or leaves. The original straw was somewhat higher in nitrogen than the other organic materials.

To study further the reason for the slow rate of decomposition of the leaves, lignin and cellulose determinations were made, with results listed in table 3. The percentage of lignin was greater in the leaves than in the corn stover or straw. The percentage of cellulose, on the other hand, was greatest in straw and least in the leaves. The analyses of the finished manures show that the cellulose decomposed much more rapidly than the lignin.

TABLE 3. — LIGNIN AND CELLULOSE DETERMINATIONS*

	Percent Lignin	Percent Cellulose
Original leaves alone	19.16	26.37
Manure from leaves, garbage, and Cyanamid	16.16	8.88
Manure from leaves and ammonium sulfate	31.00	12.57
Manure from leaves and Cyanamid	29.60	10 20
Original corn stover	13.10	37.58
Manure from corn stover and ammonium sulfate	17.58	22.24
Manure from corn stover and Cyanamid	16.91	18.34
Original straw alone	15.76	44.41
Manure from straw and ammonium sulfate	24.03	21.83
Manure from straw and Cyanamid	23.08	19.70

*Cellulose was determined by the Cross and Bevan method. Tests were made in duplicate and the ash correction was made.

Lignin was determined by the sulfuric acid method and is corrected for lignin nitrogen. These figures then are the results of four crude lignin determinations corrected by duplicate ash and lignin nitrogen corrections

The analyses were made by John N. Everson, Department of Agronomy.

Manure Made from Leaves and Garbage

After it was found that the piles made of leaves were slow in decomposing, another pile was built using half leaves and half kitchen garbage, with Cyanamid as the nitrogen supplement. The odor of the decomposing mixture when stirred was none too pleasant, but the rate of decomposition was very rapid. The presence of the garbage seemed to speed up the slow decomposition of leaves when they were used alone. The manure made from the garbage and leaves suggests a possible way of getting rid of, and at the same time putting to good use, refuse which is plentiful in every household. From the chemical analyses in tables 1 and 2, it will be seen that the garbage-leaves artificial manure was richer in plant foods than any of the other manures.

Pot Experiment with Artificial Manure

A series of tests was run in order to compare the different artificial manures. Oats were seeded in three-gallon crocks, filled with a mixture of one part of sandy loam topsoil and three parts of fine sand. These sand cultures were treated with dried artificial manure and inorganic fertilizers as indicated in table 4. A few days after the oats had germinated and when they were about three inches tall, the plants grown on the heavier treatments of artificial manure made with Cyanamid began to show signs of toxicity which continued throughout the experiment, both height and yield of oats being less on this treatment. Analysis showed a greater percentage of nitrogen in the oats grown on manure made with Cyanamid than in those grown on manures made with ammonium sulfate, but this may have been due to the abnormality of the injured oat plants. This apparent toxicity should not be considered a serious objection to the use of Cyanamid, for the oats were grown in sand cultures and when trials were made under field conditions no such injurious effects were noticed. At the Geneva Station, Collison and Conn[3] experienced similar results when they worked with sand cultures.

TABLE 4. — POT EXPERIMENT WITH ARTIFICIAL MANURE.

Manure Made from—	Rate of Application per Acre		Yields per Pot		Nitrogen Content of Oat Plants	
	Manure Tons	Superphosphate Pounds	Height of Oat Plants Inches	Dry Weight of Oat Plants Grams	Percent	Grams
Corn stover with ammonium sulfate	10*	500	9.0	3.93	.74	.0291
	20	750	9.0	4.22	.79	.0333
	30	1,000	9.0	4.55	.84	.0382
Corn stover with Cyanamid	10*	500	11.6	5.85	1.11	.0649
	20	750	10.8	4.75	1.32	.0627
	30	1,000	9.7	4.55	1.65	.0751
Straw with ammonium sulfate	10*	500	11.0	6.91	.75	.0518
	20	750	11.5	7.85	.77	.0605
	30	1,000	14.0	8.66	.77	.0667
Straw with Cyanamid	10*	500	12.5	7.07	.89	.0629
	20	750	10.5	5.87	1.13	.0663
	30	1,000	10.0	6.05	1.14	.0690
Check—no manure	None	None	11.5	7.30	.84	.0613

*On basis of manure containing 0.5 percent nitrogen (N), that is, 100 pounds of N per acre, or 0.442 grams N per pot. The amount of dried artificial manure added to each pot was determined by the actual N content of the respective artificial manures.

Field Experiments with Artificial Manure

Field corn was planted on one hundredth acre plots, to which the different artificial manures had been applied at the rates of 10, 20, and 30 tons per acre. Yields were compared with yields from plots to which natural manure was applied at equal rates. The growing corn on plots treated with 20 and 30 tons of manure per acre was superior in growth and color to that on plots treated with 10 tons of manure per acre. There was no great difference in yield of corn between plots

[3]Collison, R. C., and Conn, H. J. Artificial manure from straw. N. Y. State Agr. Expt. Sta. Bul. 573. 1929.

treated with artificial manure and those treated with natural horse manure, except on the plots receiving the 30-ton application, where the artificial manures gave higher yields than the natural manure. (Table 5). It may be concluded that the artificial manure as prepared here is comparable to and slightly better than ordinary natural horse manure when used at high rates of application.

TABLE 5. — YIELDS OF CORN GROWN ON ARTIFICIAL MANURE.

Manure Made from —	Rate of Application per Acre Tons	Yields per Acre — Pounds		
		Field Green Weight of Corn	Field Dry Weight of Whole Ear	Field Dry Weight of Stover
Corn stover with ammonium sulfate	10*	16,023	3,620	4,135
	20	19,023	4,858	5,199
	30	20,966	5,495	5,028
Corn stover with Cyanamid	10*	15,614	3,225	4,261
	20	20,625	4,688	5,352
	30	22,432	5,625	6,007
Straw with ammonium sulfate	10*	17,386	3,876	4,763
	20	21,239	5,154	5,206
	30	24,307	6,989	6,221
Straw with Cyanamid	10*	18,750	4,176	4,988
	20	21,921	5,414	5,666
	30	22,261	6,136	6,096
Natural Manure	10*	16,466	3,705	4,575
	20	17,898	4,176	5,574
	30	18,170	4,261	5,318
4-8-4 Fertilizer	1,250 pounds	17,727	4,558	4,677

*On basis of manure containing 0.5 percent nitrogen (N), that is, 100 pounds of N per acre. The amount of dried artificial manure added to each plot was determined by the actual N content of the respective artificial manures.

Experiments with Artificial Manure as Top-Dressing

A one-year-old field of mixed grass was top-dressed with the prepared artificial manures after the first crop of hay had been harvested The second crop of grass was not harvested, but from observation looked much superior to that on the surrounding untreated plots. The following year the hay contained a greater percentage of clover than the crop from the untreated plots. The yields per acre, on the dry basis, are listed in table 6.

TABLE 6. — YIELD OF HAY GROWN ON PLOTS WITH ARTIFICIAL MANURE TOP DRESSING

Manure made from —	Yield on Dry Basis Pounds per Acre
Corn stover with	
Ammonium sulfate	5281
Cyanamid	5227
Oat straw with	
Ammonium sulfate	4541
Cyanamid	5101
Leaves and garbage with	
Cyanamid	6265
Untreated plot	3363

General Directions for the Preparation of Artificial Manures

Materials That May Be Used

Any non-woody plant material may be used in the preparation of artificial manure, such as leaves, weeds, straw, corn stover, garden and cannery refuse, lawn clippings, and even kitchen garbage if the greasy portions are disposed of in some other manner.

The manure pile may be made outdoors. A shallow pit about a foot deep can be used to advantage, but any level place will be satisfactory. Since the pile is not attractive, it should be placed in some inconspicuous spot and should be protected from the wind.

Small-Scale Preparation

Home gardeners who are going to prepare artificial manure on a small scale from the various refuse materials which they are able to collect throughout the spring, summer, and fall seasons may find it more convenient to use a ready-mixed commercial fertilizer. Any garden fertilizer, such as a 6-8-6 or 5-8-7 fertilizer, will be satisfactory and 100 pounds will be sufficient to make a pile of approximately 125 cubic feet, or a pile having dimensions of 5 feet by 5 feet by 5 feet. If higher grade fertilizers are used, the amount used should be proportional.

About 25 pounds of ground limestone can be used to advantage with each 100 pounds of fertilizer to produce a better end product and to insure against loss of plant nutrients (nitrogen) during the process of decomposition.

The pile should be built in layers, with a few handfuls of the fertilizer scattered on each new supply of organic material that is added. One or two shovelfuls of garden soil sprinkled on each layer will aid in inoculating the pile with the necessary decomposition bacteria. If the organic material is dry, it should be dampened with enough water to wet it well but not enough to leach out of the bottom of the pile. If the materials are green, such as grass clippings, no water need by added. During a dry season when rainfall is not sufficient to keep the pile fairly moist, hand watering of the pile will be necessary to produce natural decay. Shoveling the material from one pile to another two or three times during the season will tend to hasten decay and give a better decomposition.

The artificial manure is ready for use when decomposition has stopped and the plant material has lost its original structure or characteristics. Tree leaves, used alone, usually take a longer time to decompose and may retain their general outline, which, however, crumbles easily when handled.

Large-Scale Preparation

In general, the same procedure as outlined above is followed in the preparation of larger quantities of manure. The method differs mainly in more economical use of chemicals to aid the decomposition and in the fact that the whole pile is usually built at one time.

The raw materials needed are: one ton of any of the organic materials previously mentioned, 75 to 80 pounds of Cyanamid or ammonium sulfate or its equivalent from any other source of readily available nitrogen, about 70 pounds of superphosphate (16 percent), 25 pounds of muriate of potash, and 75 to 80 pounds of ground limestone. If Cyanamid is used as the source of nitrogen, no limestone is required because Cyanamid contains a large amount of calcium. For general work, the amounts do not have to be too exact. If smaller amounts of organic material are used, the chemicals should be reduced proportionately.

It is desirable to start with enough raw material to make a pile 5 to 8 feet high —about a ton of dry matter. The organic matter is piled and tramped in layers either in a circular bed about 9 feet in diameter or in a 10-foot square. The

layers should not be over 6 inches thick. The chemicals are scattered over each layer of organic material, and a shovelful or two of garden soil or barnyard manure sprinkled on each layer as the pile is being built will serve as an inoculating agent. Each layer of organic material should be sprinkled with water as it is packed down by tramping. Care should be taken that not enough water is used to leach out of the bottom of the pile. If the pile is built outdoors, the top may be left flat so as to retain rain water instead of shedding it. If the pile bgins to heat up greatly in two or three days, the temperature should be lowered by sprinkling on more water, but not an excessive amount.

After four or five weeks, the whole pile should be forked over into another pile, throwing the outside portion into the center of the new pile and adding more water. The forking-over process is repeated once more at the end of about eight weeks, and the pile is then allowed to stand until the organic material is decayed, or until the heating stops. The product may then be used in the same manner as stable manure.

Summary

Artificial manure was prepared from corn stover, mixed deciduous leaves, oat straw, and mixed leaves and garbage, in order to study the method of preparation, rate of decomposition, heat and moisture relationships, and volume and appearance of the finished product. Chemical analyses were made of the various products and they were used in both pot and field experiments.

Both chemical and vegetation tests showed that when Cyanamid or ammonium sulfate was used in the preparation of manure from corn stover, oat straw, or leaves and garbage, a finished product resembling well-rotted farmyard manure was obtained. Leaves used alone decomposed to form artificial manure very slowly, while corn stover decomposed most rapidly.

Field tests showed that artificial manure can be used satisfactorily in growing corn, and hay yields were increased considerably where it was applied.

Detailed general directions are given for both small- and large-scale preparation of artificial manure.

MASSACHUSETTS
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Breeding Rhode Island Reds for Rapid Feathering

By F. A. Hays and Ruby Sanborn

Rapid chick feathering, particularly over the back region, is a very valuable character in general purpose fowls. This study was carried on over a long period to discover a reliable method for fixing this character in Rhode Island Reds.

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Introduction

Rapid chick feathering is considered to be a very valuable character in flocks bred for high egg production. Cockerels sold for broiler purposes command a significantly higher price if they exhibit complete feathering. Rapid feathering is also thought to offer some protection against feather pulling and cannibalism during the early growing period. During the last two decades poultry breeders have given much attention to fixing this trait in the general purpose breeds

The fact has long been known that such breeds as Rhode Island Reds, Plymouth Rocks, Wyandottes, and Orpingtons show a sex-dimorphism in the rate of feathering. Females of these breeds usually develop complete feather covering at an earlier age than males. Saharova (1926) called attention to sex differences in the rate of feathering of the general purpose breeds, to the slow feathering in the Asiatic breeds, and to the rapid feathering in the Mediterranean breeds. He indicated that the dimorphic type of feathering was dominant over rapid feathering, was not sex-linked but was partly sex-limited. Danforth (1929) crossed White Leghorns, Barred Plymouth Rocks, and Rhode Island Reds and grafted skin from one breed to another. He concluded that there are two factors producing slow feathering. One of these factors is sex-linked and occurs in Rhode Island Reds. A second factor produces an inhibitory effect through the soma. Both the sex-linked and the inhibitory factor occur in Barred Plymouth Rocks.

Warren (1925) reported on the mode of inheritance of a single sex-linked recessive gene for rapid chick feathering in White Leghorns when crossed with Jersey Black Giants. Kinugawa (1927) reported the existence of a sex-linked recessive gene for rapid chick feathering in Leghorns, Hamburgs, Minorcas, and Nagoyas.

Considerable attention has been given by a number of investigators to the relation of rate of chick feathering to other important characters in laying flocks.

Martin (1929) studied the rate of chick feathering in both exhibition and production-bred Barred Plymouth Rocks. He noted that the rate of feather development over the back was closely related to rate of growth, the heavier chicks feathering the more rapidly. Barring was superior in the slow-feathering and slow-growing chicks. No linkage was found between genes for rate of back feathering and the gene M for winter pause or either sex-linked gene E or autosomal gene E′ for early sexual maturity.

Gericke and Platt (1932) investigated the effect of varying amounts of protein in the ration on feather growth in Barred Plymouth Rock chicks from hatching to 8 weeks of age. Their data indicated that higher levels of protein increased the rate of feather growth. These workers noted further that the growth of feathers was slower in the dorsal tract than in any other region except on the head and the wing bow. A high correlation was also observed between body weight and feather development. Rapid feather development offered considerable protection against feather picking.

Jaap and Morris (1937) studied the variation in body weight and rate of feathering at 8 weeks of age in six general purpose breeds and crosses. Their data indicated some association between rate of growth and rate of feathering. They found, however, that reciprocal crosses between rapid- and slow-feathered stocks gave a more or less intermediate feather development.

Radi and Warren (1938) presented rather extensive data on chick feathering in Rhode Island Reds. They reported that thyroxine injections definitely stimulated feather development; that brooding under either high humidity or low temperature improved feathering; that selection was effective in producing strains genetically different in degree of feathering at seven weeks; that superior feathering was incompletely dominant to poor feathering but the number of genes involved was not determined; and concluded that the genetic differences established were probably due to modifying factors acting upon the sex-linked dominant late-feathering gene for which the birds were known to be homozygous.

Lloyd (1939) made a study of feathering in Barred Plymouth Rocks, Rhode Island Reds, Cambars, and White Leghorns. He observed varying degrees of feathering at 4, 6, and 8 weeks of age and expressed the opinion that it is probably possible to produce uniform rapid feathering in Reds and Rocks. He believes that rapid feathering behaves as a dominant in inheritance.

At the present time there is considerable confusion regarding the mode of inheritance of rate of chick feathering. There is general agreement, however, that the general purpose breeds are normally slow in feathering and that there is a sexual dimorphism in rate of feathering. Through selective breeding in recent years considerable progress has been made in establishing rapid chick feathering in many flocks but the problem is not a simple one. A study of several phases of the problem should add important information.

Data Available

Beginning in 1931 all birds were classified at 12 days of age for the sex-linked early feathered type only, and a study was begun at the Massachusetts Station in 1933 on the mode of inheritance of rate of chick feathering in Rhode Island Reds. The primary objective was to develop a method of breeding to produce complete back feathering at 8 weeks of age. Ten generations of chicks have been examined for back feathering at 8 weeks making a total of over 30,000 examinations.

In 1934 selective breeding was begun to develop three lines with respect to chick feathering. Line 1 was bred for complete back feathering at 8 weeks. Line 2 was bred for absence of back feathering at 8 weeks. A control line included birds bred for high fecundity without regard to rate of feathering.

Throughout the experiment there was considerable difficulty in separating pullets at 8 weeks of age into rapid and slow types with respect to back feathering. In males no difficulty was experienced. Line 1 was always reproduced by sires that had complete back feathering at 8 weeks and line 2 was always reproduced by sires that had no back feathering at 8 weeks. After the first generation, female breeders were selected within their respective lines.

Records were also secured on many of the chicks at 10 days to discover the presence of the recessive sex-linked gene by the development of tail feathers. Rate of feathering in nine feather tracts was studied weekly in a number of chicks. Complete trapnest records were secured on many females to study the relation between rate of feathering and fecundity characters.

Character of the Foundation Stock

A preliminary study was made on the flock hatched in 1933 to get information on the presence or absence of the sex-linked gene for rapid feathering and the presence or absence of back feathering at 8 weeks of age. The presence of a tail at 12 days of age is produced by the recessive sex-linked gene sl. Males with tails were therefore marked slsl and males without tails were marked Sl. In a similar manner females with tails were sl and those without tails were Sl. At 8

weeks of age the birds were graded into + and − groups, depending upon the development of some back feathering or the lack of any back feathering.

A total of 1494 males was examined at 12 days and again at 8 weeks of age. At the same time 1436 females were examined and classified. The summary appears in table 1.

TABLE 1.—CHICK FEATHERING AT 12 DAYS AND 8 WEEKS OF AGE. FOUNDATION FLOCK — 1933.

	Males				Females			
At 12 Days	Sl		slsl		Sl		sl	
At 8 Weeks	−	+	−	+	−	+	−	+
Totals	1275	83	92	44	505	666	63	201

Of 1494 males examined, only 136 or 9.1 percent carried the sex-linked gene sl in homozygous condition, and 92 of these (67.6 percent) failed to develop back feathering at 8 weeks. Out of 1358 males in which there was no tail development at 12 days, 83 had back feathering at 8 weeks.

In the female population 18.3 percent carried the sex-linked gene sl, and 23.8 percent of these failed to develop back feathering at 8 weeks. Out of the total of 1172 that lacked tail growth at 12 days, 56.8 percent showed back feathering at 8 weeks.

Only 127 or 8.5 percent of the males in the foundation stock carried complete back feathering at 8 weeks, while over 60 percent of the females had complete back covering at 8 weeks. Furthermore, out of 1358 males that were not homozygous for gene sl, 6.1 percent developed back feathering in comparison with 32.4 percent in males carrying recessive gene sl.

Opportunity is given for study of the relations of the gene for early tail growth and genes for back feathering later on in this report.

Development of Feathers in Different Body Regions

Observations were made weekly for 8 weeks, on 419 chicks in lines 1 and 2 hatched in 1934 and 1935. The feather tracts studied were head, neck, breast, shoulder, back, abdomen, thigh, leg, and tail. In table 2 the sexes are recorded separately and the mean age when feather growth started and when it was completed is indicated for line 1, bred for complete back feathering at 8 weeks, and line 2, bred for absence of back feathering at 8 weeks.

TABLE 2. — MEAN AGE IN WEEKS WHEN FEATHERING STARTED AND WAS COMPLETED. 1934 AND 1935 — 419 CHICKS.

Feather Tract	Age in Weeks when Feathering Started				Age in Weeks when Feathering was Completed			
	Males		Females		Males		Females	
	Line 1	Line 2	Line 1	Line 2	Line 1	Line 2	Line 1	Line 2
Head . . .	5.08	5.49	4.81	5.23	8.00	6.00	8.00	7.00
Neck . . .	3.65	3.80	3.17	3.43	6.96	6.83	6.74	6.77
Breast . .	2.90	3.30	2.26	2.53	7.33	7.46	6.52	6.82
Shoulder.	2.61	3.05	1.78	2.11	6.15	6.34	4.38	5.30
Back . . .	4.92	5.88	3.41	4.41	7.27	7.50	7.10	7.13
Abdomen	4.19	4.51	3.92	4.28	7.70	7.75	7.51	7.59
Thigh . .	3.01	3.48	2.40	2.70	6.29	6.40	7.08	7.17
Leg	3.39	3.67	3.15	3.21	8.00	8.00	7.92	7.84
Tail	2.54	2.87	1.95	2.31	7.00	8.00	5.86	6.57

The head and the back tracts were slowest in developing feathers; the abdomen, neck, and thigh regions were also rather slow in developing; and the shoulder, breast, and tail developed feathers rather early. Males feathered more slowly than females, and there was a significant difference in age when feather growth started between lines 1 and 2.

When the age at which feathering was complete in the different feather tracts is considered, it will be noted that head, leg, and abdomen were slowest to complete feather development; the back, tail, and breast were next in order; and the shoulder and thigh regions completed feather development rather early. In almost all tracts studied, the males of line 2 were slower than those of line 1. Females in the two lines did not differ greatly in time required for complete feather development in the different feather tracts. This is in line with the previous observation that feathering phenotypes are difficult to distinguish in females.

Percentage of Chicks Completely Feathered in the Different Tracts at Eight Weeks of Age

It is desirable to learn something about stages of feather growth in the different tracts at the age of 8 weeks. Since selective breeding had just begun when these observations were made, it is self-evident that the fast and slow lines would be less diverse than in later generations.

Table 3 indicates that both lines were rather poorly feathered at 8 weeks of age when the experiment began. In line 1 only 9.91 percent of the males had complete back feathering, while in line 2 the percentage was even less, 2.94 percent.

TABLE 3. — PERCENTAGE OF CHICKS COMPLETELY FEATHERED IN THE DIFFERENT TRACTS AT 8 WEEKS OF AGE. 1934–1935.

	Males		Females	
	Line 1	Line 2	Line 1	Line 2
Head	1.74	1.10	3.45	1.03
Neck	61.21	46.15	79.31	61.86
Breast	43.97	30.77	78.45	61.86
Shoulder	56.03	38.46	99.14	83.51
Back	9.91	2.94	72.41	41.67
Abdomen	34.48	8.79	70.69	42.27
Thigh	6 03	5 49	31.03	18.56
Leg	39.66	31.87	51.72	46.39
Tail	8.62	3.30	81.90	38.14

In the females, the percentages were 72.41 and 41.67 respectively for lines 1 and 2. These data indicate that at the beginning of the experiment both lines included some rapid-feathering birds.

Relation Between Feathering at Twelve Days and Back Feathering at Eight Weeks

Records on tail development at 12 days and on feathering over the back at 8 weeks were taken on all chicks in the control group and in lines 1 and 2 for the generations hatched in 1938 and 1939. It seemed particularly desirable to study the relation between the sex-linked recessive gene sl which produces tail growth during the second week and the presence or absence of back feathering at 8 weeks of age. Since there is a sex-dimorphism, the sexes were considered separately. The chicks were classified as either rapid or slow feathering at 12 days

and the same chicks were again classified as + or − for back feathering at 8 weeks. The particular point of interest in these data is the percentage of + and − birds in the sl and Sl groups, respectively. Table 4 presents the data.

TABLE 4. — RELATION OF CHICK FEATHERING AT 12 DAYS TO BACK FEATHERING AT 8 WEEKS. 1938 AND 1939.

Chick Feathering at 12 Days	Back Feathering at 8 Weeks	Males		Females	
		Number	Percent	Number	Percent
		Control Line			
sl	+	21	95.4	108	74.5
	−	1	4.6	37	25.5
Sl	+	274	23.9	117	12.3
	−	873	76.1	838	87.7
		Line 1, Bred for Complete Back Feathering at 8 Weeks			
sl	+	39	97.5	70	78.6
	−	1	2.5	19	21.4
Sl	+	117	49.2	58	34.3
	−	121	50.8	111	65.7
		Line 2, Bred for Absence of Back Feathering at 8 Weeks			
sl	+	0	0.0	0	0.0
	−	0	0.0	1	100.0
Sl	+	6	8.3	1	1.8
	−	66	91.7	55	98.2

Almost 24 percent of the males in the control line that had not exhibited rapid feathering at 12 days of age showed back feathering at 8 weeks of age. In line 1 about half of the males that were classified as slow feathering when 12 days old developed back feathering when 8 weeks old. Only 8 percent of the males in line 2 showed back feathering when 8 weeks old. These facts suggest that the presence of the recessive gene sl in heterozygous condition causes the development of some back feathering in males at 8 weeks. The fact that almost all of the male chicks that had shown themselves to be homozygous for gene sl at 12 days later developed some back feathering, points to the sex-linked gene sl as of major importance in the development of back feathering at 8 weeks.

About 75 percent of the females showing rapid feathering at 12 days had complete back feathering at 8 weeks of age. As has been previously pointed out, every female will show some feathering on the back at 8 weeks, making a classification for back feathering difficult and of questionable reliability. For this reason, more stress has been laid on the male side of the population. Since females can carry gene sl in simplex state only, its influence on back feathering may be less in this sex. In all lines, females that lacked gene sl were much less likely than males of the same line to develop back feathering at 8 weeks.

These earlier data point to the importance of the sex-linked gene sl in its relation to feathering in the back region. Careful attention is given later to its relation to degree of feathering and to other inheritance phases of the problem.

Relation Between Feathering at Twelve Days and Degrees of Back Feathering at Eight Weeks

In the last two generations, hatched in 1941 and 1942, the chicks were all classified for the sex-linked gene at 12 days of age. At 8 weeks of age all chicks were again classified for back feathering into grades 0 to 4. Since there were so few chicks in grade 4, which implies complete feather growth on the back without any pin feathers, this grade is scarcely worth considering in these studies. Males particularly are known to vary widely in the degree of feathering over the back. The data in table 5 show how the presence or absence of the sex-linked gene sl for rapid feathering affects the degree of back feathering in Rhode Island Reds in the three lines.

There appears to be an important relationship between the recessive sex-linked gene sl for rapid feathering and the degree of feathering over the back at 8 weeks. In the control line males, slightly over 10 percent that carried gene sl in homozygous condition had no back feathering at 8 weeks of age. This fact indicates that such males must have lacked the necessary autosomal genes to produce rapid back feathering. In line 1, slsl males all had some back feathering at 8 weeks. In line 2, the sex-linked gene was not present in the males.

Since sex-linked gene sl shows its effect in females in the hemizygous or single dose stage, a greater percentage of the females than males in all three lines was observed to have tail growth at 12 days of age. Only one sl female produced in two generations, failed to develop some back feathering at 8 weeks. All other females that had tails at 12 days fell into grades 2, 3, or 4 when 8 weeks old. One very significant fact should be noted in this connection; in the control line 58 percent of sl females were graded 3 or 4 at 8 weeks, while in line 1, 96 percent were given these two grades. In other words, the sl females in line 1 after seven years of selection for early back feathering must have approached a homozygous condition for autosomal genes concerned.

Males lacking tails at 12 days may be of two genotypes, Slsl or SlSl, as far as the sex-linked gene is concerned. Table 5 shows that about 22 percent of such males lacked back feathering completely at 8 weeks in the control line and that most of the others fell in grades 1 and 2. In line 1 there were no Sl males completely lacking in back feathering and about 97 percent fell in grades 2 and 3. The Sl males of line 2 were mostly in the 0 grade for back feathering, with about 7 percent in grade 1. In line 1, selection on the basis of back feathering had been effective in the absence of the sex-linked gene. It is very probable also that the Sl males in line 1 were all heterozygous for gene sl. In the control line fewer males were heterozygous for gene sl and probably none were heterozygous for this gene in line 2.

Females that failed to develop tails at 12 days must have completely lacked the recessive sex-linked gene sl. In this group, any differences in rate of back feathering between the three lines must have been due to the effects of selection on autosomal genes. The Sl females in the control line fell mostly into grades 2 and 3 for back feathering at 8 weeks; the Sl females of line 1 fell only in grades 2 and 3; and the Sl females of line 2 were mostly in grades 1 and 2. Females of line 1 were definitely superior to the controls and those of line 2 were decidedly inferior to the controls.

Breeding Results Concerned with the Sex-Linked Gene and Other Possible Genes Affecting Back Feathering

Table 6 shows the character of the progeny produced in ten generations from eighteen different types of matings. Progeny where grouped into either + or − classes with respect to back feathering at 8 weeks of age.

TABLE 5. — RELATION BETWEEN CHICK FEATHERING AT TWELVE DAYS AND BACK FEATHERING AT EIGHT WEEKS. 1941 AND 1942.

Chick Feathering at 12 Days	Sex	Total Number	Birds Classified by Degree of Back Feathering at 8 Weeks									
			Grade 0		Grade 1		Grade 2		Grade 3		Grade 4	
			Number	Per-cent	Number	Per-cent	Number	Per-cent	Number	Per-cent	Number	Per-cent
Control Line												
sl..........	Male	38	4	10.53	15	39.47	16	42.11	3	7.89	0	0.00
	Female	81	1	1.23	0	0.00	33	40.74	45	55.56	2	2.47
Sl..........	Male	638	140	21.94	230	36.05	233	36.52	35	5.49	0	0.00
	Female	572	1	.17	18	3.15	353	61.71	196	34.27	4	.70
Line 1, Bred for Complete Back Feathering at 8 Weeks												
sl..........	Male	132	0	0.00	2	1.52	9	6.82	109	82.58	12	9.09
	Female	245	0	0.00	0	0.00	10	4.08	227	92.65	8	3.27
Sl..........	Male	99	0	0.00	3	3.03	42	42.42	54	54.55	0	0.00
	Female	10	0	0.00	0	0.00	3	30.00	7	70.00	0	0.00
Line 2, Bred for Absence of Back Feathering at 8 Weeks												
sl..........	Male	0	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
	Female	1	0	0.00	0	0.00	0	0.00	1	100.00	0	0.00
Sl..........	Male	96	89	92.71	7	7.29	0	0.00	0	0.00	0	0.00
	Female	88	5	5.68	32	36.36	47	53.41	4	4.55	0	0 00

Mating 1 was between parents both genetically pure for the sex-linked recessive gene sl, and the sires were + for back feathering. In the control line this mating gave 25 + to 5 − sons and 31 + to 16 − daughters. In line 1 all sons and all daughters showed back feathering at 8 weeks.

Mating 2 included Slsl and SlSl sires mated to sl dams. In the control line equal numbers of feathered and non-feathered cockerels appeared. The daughters showed equal numbers also. In line 1 there were twice as many + as − sons and the proportions of daughters were the same as for the sons.

Mating 3 differed from mating 1 only in that the sires used lacked back feathering. The number of progeny was very small but only 1 out of 12 sons had back feathering. The daughters all lacked back feathering. Here is further evidence of autosomal genes affecting back feathering.

Mating 4 may be compared with mating 2 for genes influencing back feathering. The data definitely indicate the same proportions of + and − daughters from both matings 4 and 2 in the control line. In line 2, however, essentially all of the sons lacked back feathering at 8 weeks, while the daughters showed 1 + to 8 −. Very likely most of the sires used in the control line were heterozygous for gene sl, while in line 2 the sires must have been SlSl.

In mating 5 the dams lacked the sex-linked gene sl for rapid feathering. When these were mated to sires pure for the sex-linked gene sl and also carrying rapid back feathering, equal numbers of + and − sons appeared; while if the sex-linked gene sl were alone responsible for back feathering, there should be no sons with back feathering. If the sires used in this mating carried a dominant autosomal gene X for rapid back feathering that the dams lacked, equal proportions of + and − sons and daughters would result. This type of mating in line 1 gave 41 + to 12 − sons or about 3 to 1. In the daughters the proportions were about 5 to 1. In this line both sires and dams may have been heterozygous for gene X which would give a 3 to 1 ratio. The excess of + females may have been due to faulty classification for back feathering.

Mating 6 was between sires that were either heterozygous for gene sl or lacked this gene entirely and were + for back feathering and dams that lacked gene sl. In the control line this type of mating gave equal numbers of + and − males and females. Very likely the sires were heterozygous for gene X and the dams lacked gene X. In line 1 the proportion of + and − sons was about 1 to 2 and the daughters showed proportions of 3 to 2. It is probable that some sires in line 1 lacked gene X.

Legends for Plates

Plate I. Chicks at 12 Days of Age.

1. Presence of gene sl — Female W2808 from line 1.
2. Absence of gene sl — Male W3148 from line 1.
3. Presence of gene sl — Female W2809 from line 1 male on line 2 female.
4. Heterozygous for gene sl — Male W3105 from line 1 male on line 2 female.
5. Absence of gene sl — Female W2796 from line 2.
6. Absence of gene sl — Female W3126 from line 2 male on line 1 female.

Plate II. Chicks at 4 Weeks of Age.

1. Grade Sl 2 — Male W3148 from line 1.
2. Grade sl 3 — Female W3116 from line 1.
3. Grade Sl 0 — Male W3105 from ine 1 male on line 2 female.
4. Grade sl 3 — Female W3104 from line 1 male on line 2 female, sister to No. 3.
5. Grade sl 0 — Female W2797 from line 2.
6. Grade Sl 0 — Female W3199 from line 2 male on line 1 female.

Plate III. Chicks at 8 Weeks of Age.

1. Grade Sl 3 — Male W1037 from line 1. His dam evidently carried an inhibitor of sl gene.
2. Grade sl 3 — Male W1070 from line 1.
3. Grade Sl 3, carries gene sl — Male W1140 from line 1 male on line 2 female.
4. Grade sl 3 — Male W1123 from line 1 male on line 2 female.
5. Grade Sl 0 — Male W823 from line 2.
6. Grade Sl 0 — Male W947 from line 2 male on line 1 female.
7. Grade Sl 2 — Male W1094 from line 2 male on line 1 female.

1

2

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Plate I. Chicks at 12 Days of Age.

4

5

6

Plate I. Chicks at 12 Days of Age.

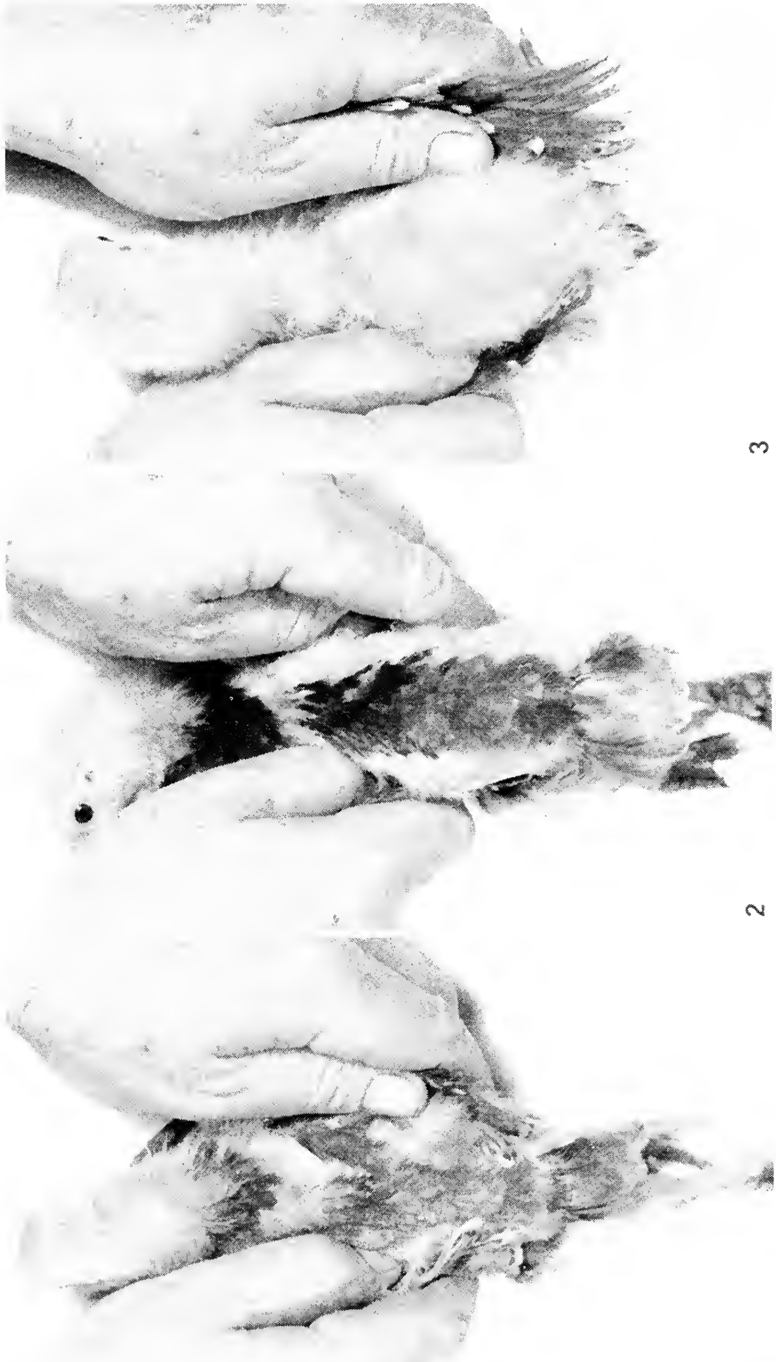

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Plate II. Chicks at 4 Weeks of Age.

4 5 6

Plate II. Chicks at 4 Weeks of Age.

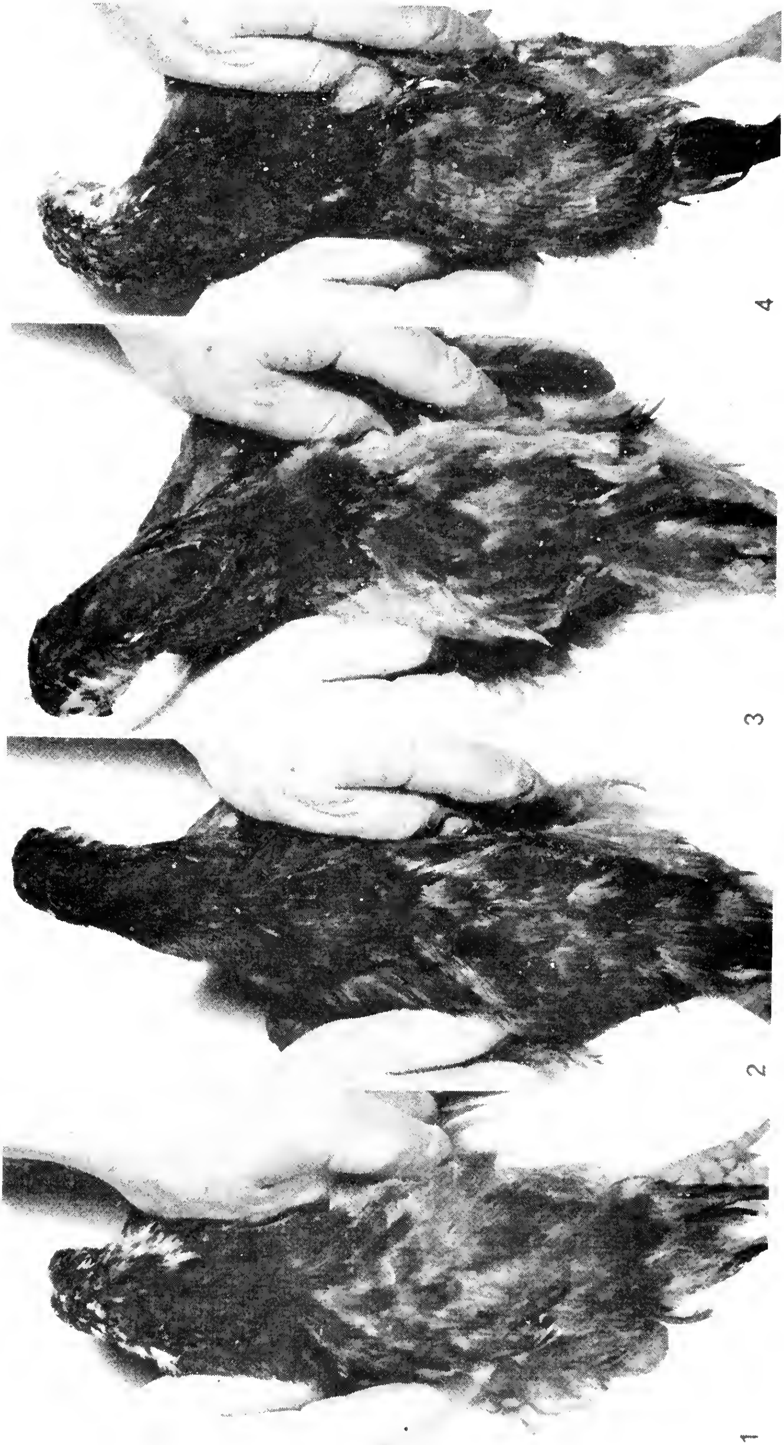

Plate III. Chicks at 8 Weeks of Age.

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Plate III. Chicks at 8 Weeks of Age.

Table 6. — Character of Progeny Produced From Different Types of Matings. 1934 — 1942.

Mating No.	Sire	Dam		Progeny Classified According to Back Feathering at 8 Weeks					
				Control Line		Line 1		Line 2	
				+	—	+	—	+	—
1	slsl +	sl	Sons	25	5	78	0		
			Daughters	31	16	86	0		
2	Sl +	sl	Sons	80	75	115	55		
			Daughters	77	78	111	55		
3	slsl —	sl	Sons	1	11				
			Daughters	0	16				
4	Sl —	sl	Sons	71	73			1	53
			Daughters	63	72			5	40
5	slsl +	Sl	Sons	21	18	41	12		
			Daughters	20	12	47	9		
6	Sl +	Sl	Sons	391	364	36	65		
			Daughters	348	319	72	52		
7	slsl —	Sl	Sons	1	36				
			Daughters	1	18				
8	Sl —	Sl	Sons	204	553			7	198
			Daughters	241	539			59	125
9	Sl	Sl	Sons	13	183				
			Daughters	50	132				
10	slsl +	+ or —	Sons	19	0	33	0		
			Daughters	13	0	33	0		
11	Sl +	+ or —	Sons	123	19				
			Daughters	163	0				
12	Sl —	+ or —	Sons	42	84			3	42
			Daughters	65	48			43	1
13	+	sl	Sons	5	9	76	5		
			Daughters	3	12	62	34		
14	—	sl	Sons	6	6				
			Daughters	12	1				
15	+	Sl	Sons	8	28	37	28		
			Daughters	8	20	34	22		
16	—	Sl	Sons	8	0				
			Daughters	15	0				
17	+	+ or —	Sons	400	580	260	351		
			Daughters	329	556	252	319		
18	—	+ or —	Sons	163	513			58	154
			Daughters	149	463			68	152

Mating 7 made use of slsl — sires on Sl dams. The progeny here of both sexes was essentially all — in back feathering. Gene sl carried pure by the daughters failed to give back feathering, and gene X must have been absent.

Mating 8 was between sires that lacked both early tail growth and back feathering and females lacking gene sl for early tail development. In the control line, this mating gave 204 + to 553 — males and 241 + to 539 — females; in line 2, the males were essentially all without back feathering. This difference between the male progeny from the two lines was apparently traceable to the presence of sex-linked gene sl in heterozygous condition in some sires used in the control line and its absence from sires used in line 2.

Mating 9 was made in 1932 and 1933 between birds classified only for the sex-linked gene at 12 days of age. This early generation produced 13 + sons to 183 —. The daughters showed the proportions of 50 + to 132 — at 8 weeks. Back feathering in the sons could not appear if produced by the sex-linked gene sl unless an inhibitor to rapid feathering such as pointed out by Warren (1933) had been present in some of the dams. It seems more likely that an autosomal gene affecting back feathering was present in a few birds.

Mating 10 included sires pure for gene sl and having back feathering at 8 weeks mated to unclassified dams. A small number of such matings gave only ¼ sons and daughters both in the control line and in line 1. The number of matings was too small to give conclusive results.

Mating 11 was made between sires either heterozygous or homozygous for gene Sl for slow feathering but showing back feathering at 8 weeks and unclassified dams. From such matings almost all of the sons and all of the daughters had back feathering, probably due to autosomal genes concerned.

In mating 12, sires not homozygous for the sex-linked gene for rapid feathering and lacking back feathering at 8 weeks were mated to unclassified dams. In the control line one-third of the sons had back feathering, probably inherited from their dams. More than half of the daughters showed back feathering. These results are in marked contrast to those of mating 11 where ¼ sires were used. In line 2, the sons were essentially all slow in back feathering while the daughters showed back feathering.

Mating 13 should be a superior mating from the standpoint of combining genes for back feathering with the sex-linked gene for rapid feathering in the sons. In the control line the progeny were too few to give accurate information. In line 1, however, the feathering behavior of the sons indicates the desirability of combining sex-linked gene sl with other genes affecting back feathering. The daughters from these matings lacked gene sl and were rather poorly feathered.

Mating 14 need not be considered because of the very few progeny produced.

Mating 15 shows the results from mating males with back feathering to females lacking the sex-linked gene sl for rapid feathering. In the control line only a small percentage of both sons and daughters was feathered at 8 weeks. In line 1 this type of mating gave about equal numbers of feathered and unfeathered sons and daughters at the age of 8 weeks. This is in contrast with mating 13 where most of the sons were feathered when they received the gene sl.

Mating 16 need not be considered because of very limited data.

Mating 17 was an important type of mating and was used extensively. Sires were selected for back feathering at 8 weeks and these were mated to the general run of dams in the flock. In the control line about two-fifths of the sons had back feathering while about three-eighths of the daughters were similarly classified. In line 1, about two-fifths of both sons and daughters were feathered. These proportions suggest that the sires did not breed true for rapid back feathering, which might seem to indicate a heterozygous condition for a single dominant autosomal gene.

Mating 18 may be compared with mating 17. In mating 18 the sires lacked rapid back feathering. In the control line this type of mating gave one-fourth of the sons with rapid back feathering and about the same proportion of daughters

TABLE 7. — BREEDING PROGRESS FOR BACK FEATHERING AT EIGHT WEEKS. 1934 — 1942.

Year	Sex	Control Line					Line 1, Bred for Complete Back Feathering at 8 Weeks					Line 2, Bred for Absence of Back Feathering at 8 Weeks				
			+		−			+		−			+		−	
		Total Number	Number	Per-cent	Number	Per-cent	Total Number	Number	Per-cent	Number	Per-cent	Total Number	Number	Per-cent	Number	Per-cent
1934	Male	510	173	33.92	337	66.08	123	45	36.59	78	63.41	130	3	2.31	127	97.69
	Female	497	247	49.70	250	50.30	144	105	72.92	39	27.08	110	23	20.91	87	79.09
1935	Male	392	93	23.72	299	76.28	120	46	38.33	74	61.67	88	32	36.36	56	63.64
	Female	368	69	18.75	299	81.25	120	44	36.67	76	63.33	119	38	31.93	81	68.07
1936	Male	236	107	45.34	129	54.66	139	68	48.92	71	51.08	58	20	34.48	38	65.52
	Female	229	110	48.03	119	51.97	138	71	51.45	67	48.55	48	28	58.33	20	41.67
1937	Male	585	219	37.44	366	62.56	201	71	35.32	130	64.68	27	0	0.00	27	100.00
	Female	504	171	33.93	333	66.07	174	54	31.03	120	68.97	26	1	3.85	25	96.15
1938	Male	644	160	24.84	484	75.16	129	57	44.19	72	55.81	39	6	15.38	33	84.62
	Female	586	132	22.53	454	77.47	120	66	55.00	54	45.00	27	1	3.70	26	96.30
1939	Male	525	135	25.71	390	74.29	149	99	66.44	50	33.56	33	0	0.00	33	100.00
	Female	514	93	18.09	421	81.91	138	62	44.93	76	55.07	30	0	0.00	30	100.00
1940	Male	570	162	28.42	408	71.58	100	59	59.00	41	41.00	45	1	2.22	44	97.78
	Female	539	115	21.34	424	78.66	99	40	40.40	59	59.60	44	0	0.00	44	100.00
1941	Male	377	316	83.82	61	16.18	140	140	100.00	0	0.00	49	5	10.20	44	89.80
	Female	369	367	99.46	2	.54	157	157	100.00	0	0.00	40	36	90.00	4	10.00
1942	Male	299	216	72.24	83	27.76	91	91	100.00	0	0.00	47	2	4.26	45	95.74
	Female	284	284	100.00	0	0.00	98	98	100.00	0	0.00	49	48	97.96	1	2.04

with rapid back feathering. In line 2 there was a very similar classification of sons and daughters. While mating 17 was more effective than mating 18 in increasing the percentages of sons and daughters with rapid back feathering, it could not be considered to be a very rapid method.

Progress in Breeding for Rapid Back Feathering — 1934 and 1942

This project was begun in the spring of 1934 with the primary objective of developing line 1 for complete back feathering at 8 weeks of age and line 2 for complete lack of back feathering at 8 weeks of age. This was the basis used in selecting both sires and dams throughout the experiment. As previously pointed out, a classification of female chicks at 8 weeks of age is difficult and uncertain because of sex-dimorphism in rate of feathering in the general purpose breeds.

In table 7 the gross data are presented for the three lines and may be used as a measure of progress through this system of breeding.

The sons and daughters in the control line were rather similar in percentage of rapid back feathering in respective years. In the first generation about 34 percent of males and about 50 percent of females exhibited rapid back feathering. In the control line there was no significant change through seven generations. In the last two generations, however, there was a very marked increase in the percentage of rapid back feathering in both sexes. This remarkable increase appears to have been due to a more extensive use of + sires to produce these generations.

Line 1, bred for complete back feathering at 8 weeks, shows rather consistent though not rapid progress in the desired direction. In the last two generations the desired goal appears to have been reached, with all males and females marked positive at 8 weeks of age.

In line 2, reproduced entirely by sires lacking back feathering at 8 weeks, a small percentage of males and a greater percentage of females generally showed some back feathering. This fact can be explained only by assuming that some dams must have transmitted rapid back feathering.

In general, the data in table 7 indicate that the selection of breeding sires on the basis of rapid back feathering is an effective though rather slow method of establishing rapid back feathering as a flock characteristic.

Breeding Progress with the Sex-Linked Gene for Rapid Feathering

Records were taken at 12 days of age for the presence of the sex-linked gene sl on five generations throughout the experiment. It should be borne in mind that no selective breeding was practiced to establish this gene in the flock. Selective breeding was based solely on back feathering at 8 weeks of age. In table 8 the percentages of males and females of the two possible phenotypes in the three lines are recorded in five generations.

In the foundation stock 9 percent of the males carried gene sl in homozygous condition and 18 percent of the females carried gene sl in hemizygous condition. In the control line there was no increase in the percentage of males or females exhibiting this gene in ten generations.

In line 1 there was a regular and consistent increase in the percentage of males and females showing the sex-linked rapid feathering gene in five generations. In the last generation, hatched in 1942, over 69 percent of the males and about 95 percent of the females showed this character. The fact is very evident from these data that males selected for superior back feathering at 8 weeks were males that carried gene sl in homozygous condition. It seems very probable that complete rapid back feathering could have been fixed in a very short time if males selected for sires had been required to show the sex-linked gene at 12 days

TABLE 8. — BEHAVIOR OF SEX LINKED GENE sl FROM 1933 TO 1942.

Year	Sex	Control Line					Line 1, Bred for Complete Back Feathering at 8 Weeks					Line 2, Bred for Absence of Back Feathering at 8 Weeks				
			sl		Sl			sl		Sl			sl		Sl	
		Total Number	Number	Percent	Number	Percent	Total Number	Number	Percent	Number	Percent	Total Number	Number	Percent	Number	Percent
1933	Male	1494	136	9.10	1358	90.90										
	Female	1436	264	18.38	1172	81.62										
1938	Male	644	5	.78	639	99.22	129	3	2.33	126	97.67	39	0	0.00	39	100.00
	Female	586	74	12.63	512	87.37	120	29	24.17	91	75.83	27	0	0.00	27	100.00
1939	Male	525	17	3.24	508	96.76	149	37	24.83	112	75.17	33	0	0.00	33	100.00
	Female	514	71	13.81	443	86.19	138	60	43.48	78	56.52	30	1	3.33	29	96.67
1941	Male	377	21	5.57	356	94.43	140	69	49.29	71	50.71	49	0	0.00	49	100.00
	Female	369	59	15.99	310	84.01	157	152	96.82	5	3.18	40	1	2.50	39	97.50
1942	Male	299	17	5.69	282	94.31	91	63	69.23	28	30.77	47	0	0.00	47	100 00
	Female	284	22	7.75	262	92.25	98	93	94.90	5	5.10	49	0	0.00	49	100 00

and complete back feathering at 8 weeks and had been mated exclusively to females having the sex-linked gene at 12 days.

In line 2 a small percentage of females showing the sex-linked gene sl appeared in 1939 and again in 1941. These may have come from sires heterozygous for gene sl. The fact is also important that every single male in this line failed to develop a tail at 12 days of age.

Since females can carry the recessive sex-linked gene sl for rapid feathering only on their single sex chromosome, it is easy to discover such females at 12 days of age by tail development. Records were taken on a number of females hatched in 1938 and 1939. These females were divided into two groups, sl for rapid feathering and Sl for slow feathering. Only those individuals that completed a full laying year were included. Table 9 gives the summarized data.

TABLE 9. — RELATION BETWEEN THE SEX LINKED GENE FOR RAPID CHICK FEATHERING AND CHARACTERS AFFECTING FECUNDITY, EGG PRODUCTION, AND MORTALITY RATE IN FEMALES.

		sl Group	Sl Group
Number of birds		24	211
Age at first egg	Days	188	186
Weight at first egg	Pounds	6.0	5.9
Winter pause	Days	8	12
Winter clutch	Eggs	3.6	3.7
Winter production	Eggs	102	100
Egg weight to Jan. 1	Ounces per dozen	23.7	23.4
Persistency	Days.	345	347
Annual production	Eggs.	231	231
Laying house mortality	Percent	35	29

The two groups of females were almost identical in such fecundity characters as age at first egg, weight at first egg, winter pause duration, winter clutch, and annual persistency, as well as in winter and annual egg production. The mean egg weights up to January first were not significantly different. Mortality rates for 365 days in the laying houses were essentially the same. In general, these data appear to indicate that the sex-linked gene for rapid chick feathering is independent of genes associated with high fecundity in Rhode Island Reds.

Relation of Chick Feathering to Body Weight and Mortality Rate in Males

All males on which the feathering record was taken at 12 days were divided into rapid and slow groups. All other males had their feathering record taken at 8 weeks of age and are grouped as + or − for back feathering. The body weight was taken on each individual at 5 months of age and the mortality rates up to 5 months were recorded for each of the four groups.

The data on the sex-linked gene Sl were secured in 1938, 1939, and 1941 and only a very small number of the slsl cockerels was retained up to 5 months of age. The data on back feathering were collected each year beginning in 1934. In table 10 the records on back feathering for 1938, 1939, and 1941 were omitted because all of these cockerels were included in the slSl classes for those years.

Unfortunately the number of males in the slsl class that were retained to 5 months of age was too small to permit an accurate evaluation of this class as compared with the Sl class. The data show, however, that the slsl cockerels were of about the same body weight at 5 months of age as the Sl cockerels

Mortality rates were low in both groups, but the data are not adequate to show differences.

A comparison of the + and − groups with respect to back feathering at 8 weeks shows the two groups to be very similar in body weight. In mortality rate the + group was somewhat lower than the − group, although the rates were low in both classes.

Table 10. — Relation of Chick Feathering to Body Weight and Mortality Rate in Males. 1934 – 1941.

Feathering Class	Number of Birds	Body Weight at 5 Months Pounds	Number of Birds	Mortality Rate to 5 Months Percent
Chick feathering at 12 days				
Rapid (slsl)	13	6.29	12	0.00
Slow (Sl)	532	6.28	549	3.10
Back feathering at 8 weeks				
Feathered (+)	275	6.08	281	2.13
Bare (−)	561	6.11	580	3.28

The data in table 10 do not in general indicate superior growth in rapid feathering cockerels up to 5 months of age. There is some evidence, however, to indicate a lower mortality rate in the rapid feathering groups.

Special Results of Matings in 1942

In addition to the regular complement of females from line 1, three females from line 2 were mated to the line 1 sire to study the inheritance of the sex-linked gene sl and other genes affecting degree of back feathering. In these matings each bird was classified for the recessive sex-linked gene sl by the presence or absence of tail growth at 12 days. All individuals were also graded for degree of back feathering at 8 weeks of age into grades 0, 1, 2, 3, and 4. For example, slsl 4 means that the male had a tail when 12 days old and also had complete back feathering at 8 weeks of age.

The first mating of the slsl 4 male and a sl 3 female gave only slsl 3 sons and daughters. A second mating of the slsl 4 male to a Sl 1 female gave 2 Sl 0 sons, 3 Sl 1 sons, 9 Sl 2 sons, and 4 Sl 3 sons. This is a ratio of 12 intermediate (grades 1 and 2) to 4 grade 3 to 2 grade 0. It seems probable that the sire was slslXx in genetic makeup and that the dam was SlXx. Such a mating should give all male progeny heterozygous for gene sl, of which 25 percent should be SlslXX, 50 percent SlslXx, and 25 percent Slslxx. The actual proportions were 4–12–2. The 11 daughters were all placed in grade 3 (sl 3). A third mating was made between the slsl 4 male and a Sl 2 female. This mating gave 14 sons, all heterozygous for gene sl. In back feathering there were 3 grade 3, 10 intermediate, and 1 grade 0. The expectation was 1–2–1 or 4 2/3 to 7 to 4 2/3. From this last mating there were 9 grade 3 daughters and 1 of grade 2, all carrying recessive gene sl.

A cross was also made between line 1 and line 2, using an sl 3 dam from line 1 mated to the line 2 sire which was SlSl 0 in makeup. This sire was homozygous for gene Sl and gave 13 sons, all graded Sl 2. The 19 daughters were also all graded as Sl 2. As was to be expected on the basis of a single autosomal factor, all sons and daughters were intermediate in back feathering. All 32 progeny failed to exhibit the recessive sex-linked gene for rapid feathering.

Types of matings made in line 1 for 1942 may be briefly considered. Two sires, both graded slsl 4, were used for breeding. These males were mated to five dams graded sl 3. The type of mating must have been slslXX sire and slXX dam. From these matings 32 sons and 41 daughters were recorded. All sons were graded slsl 4 as would be expected. All daughters were graded sl 3, except two which were graded sl 2. It is very evident that these sires and dams bred true for rapid back feathering as well as for the sex-linked gene sl.

Types of matings in line 2 may also be examined. A single sire was mated to a number of different dams. Mating the SlSlXx sire to Sl 1 females gave 9 Sl 0 sons and no other types. There were 4 Sl 1 daughters and 4 Sl 2 daughters from this mating. The dams were probably SlXx in genetic makeup The slow feathering sire of line 2 was mated to one dam graded Sl 2. All sons produced were Sl 0 in grade. Out of 4 daughters, 3 were medium in back feathering and 1 graded 0. All lacked the sex-linked gene sl.

The mode of inheritance of rapid back feathering appears to be somewhat involved. The sex-linked recessive gene sl appears to play an important role in relation to the degree of back feathering. Specific matings made in 1942 to test the relation between the sex-linked gene for rapid feathering and possible autosomal genes for rapid back feathering point definitely to the sex-linked gene sl as essential to secure complete back feathering at 8 weeks of age. This recessive gene sl need not be in homozygous condition to produce complete back feathering in an individual male, but from the standpoint of his breeding ability it is highly desirable that he be homozygous for gene sl.

Evidence seems to point to a single dominant autosomal gene X which has a cumulative effect and must be supplemented by recessive gene sl to give complete rapid back feathering. Sexual dimorphism in the rate of back feathering in Rhode Island Reds renders the grading of females for back feathering an uncertain procedure. On the basis of these studies, it seems evident that in breeding for rapid back feathering two procedures will quickly accomplish the desired end. (1) Both breeding males and females should be selected at 10 to 12 days of age for the presence of the recessive sex-linked gene sl. (2) The same birds that showed tail development on the first examination should be graded for back feathering at 8 weeks of age, and only those with complete back feathering should be placed in the breeding pens.

Males of different grades with respect to back feathering at 8 weeks appear to have the genetic composition indicated below:

Grade	Genotype	Grade	Genotype
0	SlSlxx	2	slslXx
	SlSlXx		SlslXx
1	SlSlXX	3	slslXX
	slslxx		SlslXX

Representative photographs of the 1942 generation are shown in Plates I, II, and III.

Summary

This report covers the period from 1931 to 1942 during which a study was made on the mode of inheritance of rapid feathering in Rhode Island Red chicks. Some of the more important deductions are:

1. Rhode Island Reds are normally sexually dimorphic with respect to rate of feathering in chicks. Under continued selection for rapid feathering, this sex-dimorphism almost completely disappears.

2. Rapid chick feathering was not consistently associated with greater weight at sexual maturity.

3. There was some evidence that rapid feathering in males is associated with a lower mortality rate to the age of 5 months.

4. The presence of the gene sl for rapid feathering, at least in heterozygous condition, in males is essential for the development of complete back feathering at 8 weeks of age.

5. Complete feathering required a longer period for development in the back region than in any of the other major body regions.

6. A dominant autosomal gene X exerts a cumulative effect with recessive sex-linked gene sl to produce complete feathering over the back at 8 weeks and to essentially eliminate sex-dimorphism in rate of feathering.

7. Either gene X alone in homozygous condition or gene sl alone in homozygous condition may produce slight back feathering in males at 8 weeks.

8. Progress in breeding for rapid back feathering was slow when breeding males were selected solely on the basis of feather development at 8 weeks of age.

9. No relation was found between the sex-linked gene for rapid chick feathering and several important inherited characters affecting egg production.

10. Results from a number of special matings indicate two procedures in selecting breeding stock that will establish gene sl, the recessive sex-linked gene for early tail growth, and gene X, the dominant autosomal gene for back feathering, in a short period.

(A) Classify all prospective breeding males and females when 10 to 12 days of age for gene sl.

(B) At 8 weeks of age definitely select both males and females that showed gene sl at 10 to 12 days and have complete back feathering at 8 weeks of age.

12. There was no indication that selective breeding for rapid back feathering will produce undesirable effects from the standpoint of egg production.

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MASSACHUSETTS

AGRICULTURAL EXPERIMENT STATION

Bulletin No. 397 December 1942

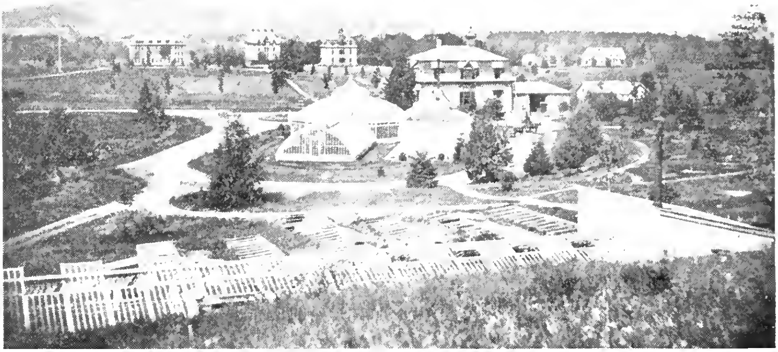
A Civilian Program for Tree Protection

By Malcolm A. McKenzie

Public appreciation of shade trees in Massachusetts is evidenced by the extensive and varied planting throughout the State. This bulletin, prepared primarily to promote municipal tree management, also suggests methods of tree care in general.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.



View of Massachusetts State College campus taken about 1880, illustrating how starkly buildings stand out when tree cover is absent.

View of Massachusetts State College campus 1942, taken from approximately the same spot as the earlier photograph and showing how tree cover obscures outlines of buildings and renders target indistinct.

A CIVILIAN PROGRAM FOR TREE PROTECTION

By Malcolm A. McKenzie, Research Professor of Botany[1]

INTRODUCTION

The appreciation of shade trees, widespread in the life of the American people, is of paramount importance in Massachusetts, and in the spring of 1942 there was a marked increase in the number of requests for the investigation of tree casualties. Trees were reported to be afflicted with diseases and other defects, and the urgency of the demand for the completion of field and laboratory studies was promptly recognized.

Healthy trees should be highly prized by all communities, but seriously weakened trees may be dangerous liabilities. A tree or limb which falls on a highway (Fig. 1) may injure a pedestrian, delay the transportation of troops and war materials, damage an automobile, or destroy electric light, telephone, fire alarm and telegraph services. During normal times the temporary incapacity of the injured person may not be a serious loss, damage to an automobile may be covered by insurance, and the public utilities' supply of replacements may be ample for all demands. During wartime, however, delay in movement of men and material and the loss of man hours is tragic, a destroyed automobile is irreplaceable, and the loss of electric light, telephone, fire alarm and telegraph service may mean failure in transmission of air-raid and fire alarms and in mobilization of aid. Air bases, air fields, defense centers, and military or naval defense areas may be isolated and unable to function. Therefore, these investigations were undertaken with the twofold purpose of learning what significant defects were present in trees and what treatment might be given to prevent damage to persons and property. From one point of view the objectives are closely related. A tree which is or can be made reasonably sound can be a reasonably safe tree. The cruxes of the problem are the recognition of various tree defects and the timing of their discovery and treatment.

The Massachusetts law (G. L. chap. 87) provides that each municipality be officered by a person responsible for "all trees within a public way or on the boundaries thereof"; in towns, a tree warden; in cities, a forester or corresponding official. In section 1 of chapter 41 of the General Laws, the term of office for tree wardens in towns was limited to one year. If, however, a town adopts the amendment passed by the General Court in 1939, the tree warden may have a term of three years, thereby providing for a measure of continuity for municipal tree programs. Very serious consideration should be given to the matter of providing adequate appropriations for tree work, and as an emergency measure, a supplementary program for tree protection under the direction of the tree warden or other responsible officer appears necessary and is recommended.

[1] The writer is indebted to Professor A. Vincent Osmun, Head, Department of Botany, for valuable assistance, suggestions and criticisms during the preparation of this bulletin. Acknowledgment is also made to Dr. S. J. Ewer, Technical Assistant in Botany, for criticism of the manuscript and the preparation of certain of the illustrations. The helpful interest of the Massachusetts Tree Wardens' and Foresters' Association, the Massachusetts Horticultural Society, the Massachusetts Forest and Park Association, the New England Telephone and Telegraph Company, the Western Massachusetts Companies, the Boston Edison Company, the Municipal Lighting Association of Massachusetts, the New England Power Association, the New England Gas and Electric Association and the New England Section of the International Municipal Signal Association has played an important part in completing this work; particular credit should be given to Mr. A. Warren Stewart, President of the Massachusetts Tree Wardens' and Foresters' Association.

TREES IN WAR

In time of peace the annual value of the tree crop in the United States, principally in manufactured forest products, approaches $800,000,000 and in wartime this figure may be more than doubled. Therefore, the importance of wood and other tree products is widely recognized. The essential value of shade tree programs during wartime, however, has not been universally appreciated. The use of trees and other plants has always been important for the concealment of unsightly areas and for securing privacy about dwellings. Since the battleground of modern war is limitless, including the homes in cities and towns throughout the world, any increased obscurity associated with native tree plantings is of significance as supplementary protection against aerial attack.

The decentralizing of municipalities or the expansion of communities into subdivisions has been a matter of research involving many considerations, especially in recent years. When the decentralizing of cities began in the United States it was not with any thought of making the communities less vulnerable as targets, but rather for the constructive benefits of peaceful pursuits including convenience, health, safety, and general welfare. Fortunately, civic planning, perhaps unwittingly but nevertheless genuinely, anticipated the future and materially contributed to the present-day war effort. Recently, R. P. Breckenridge,[2] Major, Corps of Engineers, Fort Belvoir, Virginia, published this heartening description under a photograph: "Aerial view of a well-planted city. Trees screen this area and render it practically immune to aerial attack." A second photograph bore this gloomy prediction: "A city where tree planting has not been considered important. Note the vulnerability and visibility to aerial attack." Major Breckenridge pointed out in particular that trees and natural foliage are obviously of prime importance in any camouflage scheme.

The development of war housing projects has added heavy duties to some municipal tree programs, and there is not time for all municipalities to provide additional tree canopies, but all towns and cities can make judicious use of the trees already planted on streets and roadsides. Spraying for the prevention of attacks by destructive pests will aid materially in enabling trees to render important service and every community should provide for tree protection. The dangers of the policy of "too little and too late" were never more clearly apparent than in the war on plant pests. Let no one be lulled into complacency concerning the imminence of attack by disease fungi and insects. Too often, ground lost to these invaders can never be recaptured. The economic loss sustained by unwarranted curtailment of pest control programs finally reaches every individual in the nation. The danger of winning the war only to lose the peace was never more real than in relation to the control of plant diseases and insect pests, and the importance of unbroken continuity in a pest control program cannot be emphasized too strongly. The ample scientific basis for this statement, although somewhat involved, may be visualized as the pattern from which "blitzkrieg" tactics were copied.

Trees protected from pests are in turn a safeguard to life and property. Moreover, the sprayers, trucks, hose lines, and storage tanks employed in shade tree protection may serve other use in an emergency. The tree wardens were among the first public officers to make specific study and provisions for a revision of local programs in cooperation with public service agencies. In fact, on November

[2] The Use of Trees in Camouflage. Trees, Sept.—Oct., 1941. pp. 7 and 15.

15, 1941, they published recommendations[3] which should materially facilitate the operation of the war emergency work of tree programs.

In brief, then, in view of the camouflage value of shade trees (Frontispiece), municipal tree planting and protection programs previously developed for the promotion of peaceful pursuits may now enable communities which were interested in living better, also to live longer.

INVESTIGATIONS

The present studies included forest and shade trees in all sections of the State, with special attention to street plantings. The principal types of troubles found are analyzed briefly.

Fungus Diseases and Insect Pests. Insects[4] contributing to tree injuries have been found to include insects causing initial injury to healthy tissues, insects associated with secondary injury to tissues previously weakened, and insects which serve as vectors or carriers of other pests. Fungi and bacteria related to tree injury include organisms which may kill trees promptly, induce ch onic disease, or cause disintegration of portions of weakened trees.

Dutch Elm Disease. The Dutch elm disease has been found in only seven trees in Massachusetts, but mention of it is included here to call attention to the importance of keeping this disease in check in any program concerned with the elimination of hazardous trees. Extensive spread of the disease would doubtless result in greatly increasing the number of dangerous street trees. (For additional information see tailpiece.)

Wood-destroying Fungi. It often happens that a limb broken from a tree during a wind storm had been previously weakened as a result of decay following invasion by wood-destroying fungi (Fig. 2). Sometimes evidence of this weakness prior to the break may be completely lacking, but in many instances it might have been detected had the tree been inspected. If a tree shows extensive signs of decay, limbs which may be broken by the wind should be removed, as in the case of the tree shown in figure 3.

Physiological Disorders. Trees, like all other green plants, require water, nutrients, sunlight, and air in order to function as living organisms. The lack or excess of some of these essentials may result in injury or death. Thus, trees sometimes suffer from drought, flood, alteration of water table, winter conditions, shade, evaporation, non-availability of nutrients, and other inherent or induced soil conditions.

Chemical Injury. Calcium chloride and other chemicals stored or applied in locations which permit contact with the soil about trees may cause injury to roots. In the atmosphere, some of these materials may cause the burning of foliage.

Smoke Injury. Smoke and fumes frequently contain sulphur compounds or other toxic substances which may injure trees with which they come in contact.

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[3] Recommended Principles and Practices of Massachusetts Tree Wardens' and Foresters' Association and Public Service Agencies.

[4] Inquiries concerning specific insect pests or their control should be addressed to the Department of Entomology, Massachusetts State College, Amherst, Massachusetts.

Similar injury[5] was observed on foliage exposed to sulphur dioxide fumes from a defective electric refrigerator.

Fire. The huge losses resulting annually from forest fires are already known to most persons, but the knowledge of how a fire injures individual trees is apparently not so well understood. Extensive injury to the trunk and branches of shade and ornamental trees often results from the burning of rubbish nearby, and scorching of the bark is sometimes the prelude to invasion by fungi.

Injury from Illuminating Gas. Many trees have been killed from the effects of illuminating gas in the soil. Usually by the time the gas injury shows in a tree, no remedial treatment is practical. In recent years considerable progress has been made in detecting gas leaks by means of surveys conducted by gas companies, and tree casualties have been reduced and human lives saved by the prompt repair of leaks.

Site. Tree troubles may originate at the site in which the tree is growing. The basic nature of a possible site may be such as to make the planting of a particular type or individual tree unwarranted. After the selection of a suitable species or specimen, planting should be done in such a way as to avoid air pockets in the soil, which often prove a source of trouble later. Careful planting in a well-chosen site is the best insurance for the future growth of the tree. Sometimes after an area has been planted, new buildings or other factors may necessitate the removal or transplanting of the trees. Turf grading operations which fail to provide a needed brick- or rock-lined wall around trees are a common source of trouble. The installation of curbing, hard-surfaced roads, and sidewalks may result in root injury. Erosion of soil during these operations and under a variety of other conditions may dangerously undermine trees. Weakening of anchorage should be guarded against in all locations.

Narrow Tree Belts. In most communities, public shade trees are ordinarily planted in the space between the hard surface road and the sidewalk. In some instances this area is extremely narrow, but widening is often precluded by existing conditions. Trees restricted in this way are under a severe handicap and in most cases have been observed to do better than one would reasonably expect. Extended periods of drought or other tests of vigor, however, sometimes take a heavy toll of weak trees in narrow planting belts.

Storm Damage. Ice storms, lightning, high winds, hail, heavy rain, and snow result annually in severe damage, and storm injuries accumulated over any extended period of time may result in trees becoming serious hazards in the community. Injury initiated by the hurricane of 1938 has served as a basis for subsequent extensive damage and, in some cases, ultimate death of trees.

Girdling Roots. In planting a tree, if care is not taken to provide a hole of adequate size in which to spread the roots, there is danger that they may become wrapped around the trunk in such a manner as to choke the normal growth (Fig. 4). The ill-advised application of a fertilizer close to the base of trees may cause excessive root development and girdling about the trunks. Girdling roots are not necessarily harmful, particularly if root grafting results. When a girdling root above or below ground is detected as the cause for tree weakening, it may be severed and the constriction of the trunk somewhat relieved.

[5] McKenzie, M. A. and L. H. Jones. Injury to trees from sulphur dioxide fumes of electric refrigerators. Science 91:239-240. 1940.

Other Girdling. Wire guards, fences, and supports in contact with trees may girdle the trunks and cause permanent scars, injury, or death.

Injury by Animals. In former days the gnawing of the bark of street trees by horses was often cited as a source of injury and possibly wounds caused in this way may again become common. At present, however, damage by horses is not a serious problem although limited injury to trees may be caused directly or indirectly by some other animals.

Frost Cracks. A sudden drop in temperature may result in the withdrawal of water from the cells of the wood in a tree trunk and its fixation as ice crystals. The resulting cell shrinkage lacks uniformity and creates a tension within the woody tissue. With the development of sufficient stress, rending occurs along the grain of the wood. An accompanying loud report may be the first warning of this type of injury. The sharp lengthwise clefts commonly seen on the south and southwest exposures of trees are the ultimate wounds of this sequence. Frost ridges in which splitting of the wood results without rupturing the bark differ only in the degree to which the shrinkage of woody tissue takes place or sufficient tension develops. Many frost cracks close and heal readily (Fig. 5, A) when the shrunken tissues thaw and absorb a sufficient amount of water. Sometimes, however, a frost crack may become a permanent weak spot (Fig. 6) which will reopen each winter and may be effectively closed only by mechanical aid, such as screw rods inserted through the tree trunk at right angles to the fissure.

Slime-flux. Wet yellowish streaks extending down the limbs and trunks of trees are frequently observed to originate at an injured crotch (Fig. 6), the cut at which a branch has been severed, or in some other wound. A slimy ooze in which fermentation organisms become active may continue to flow down the surface of the bark for a considerable period of time and in persistent cases where the bark and growing tissue are continually wet, extensive injury may result.

Lost Protection. Some trees require protection from drying winds or excessive heat or cold. Since the hurricane of 1938 in which such protection was sometimes lost, resultant injury has been particularly conspicuous. Tree owners reasoned that sheltered trees survived the hurricane, but failed to evaluate critically the post hurricane exposure of these trees resulting from lost protection.

Branch Wounds. Friction resulting from the rubbing of branches or the contact of public utility wires with branches often causes wounds which may later directly or indirectly result in the death of certain parts of trees. Utility companies have long since learned that where wires are in direct contact with trees there is not only the immediate prospect of interrupted service from burning as a result of contact of the energized wire and grounded tree, but also the later penalty of the killed branch crashing through the wires.

Trunk Wounds. It is not uncommon to find the trunks of trees debarked by automobiles, snowplows, or lawnmowers. Such injuries may be the beginning of serious trouble, serving as points of entrance for decay organisms and the ultimate weakening and collapse of trees.

Unusual instances of trunk wounding, as those associated with the Connecticut Valley flood of 1936, are sometimes difficult to explain after the conditions causing them no longer prevail. For example, trees situated in locations which now appear to be at a safe distance from flooding waters show bark injury known to have been caused by ice floes.

Root Injuries. The most conspicuous root injuries are those resulting from excessive root pruning; especially the type shown in figure 7, upper. The almost certain sequel to such pruning is shown in figure 7, lower.

Neglected Pruning. Most trees require a minimum of pruning for health, appearance, disease control, safety, utility line clearance, or other considerations. Delay in pruning or failure to prune correctly may prove to be a costly mistake, especially in municipal shade tree management. Severe damage to neglected trees, injury to citizens or their property, as well as the interruption of the service of wire-using agencies, may result.

Branch Stubs. Careless pruning or storm injuries sometimes leave jagged branch stubs as an invitation to wood-destroying fungi. Probably tree deterioration starts in this way more often than in any other.

Exposed Wounds and Cuts. Many tree casualties are found to result from untreated wounds and cuts. Prompt treatment of wounds and immediate attention to cut surfaces following the removal of branches are constructive preventives useful in checking early deterioration.

Cavities. Extensive cavities in trees represent the advanced stages of progressive decay following injuries. The best treatment for them is to prevent their occurrence, or check their progress.

Dangerous Trees. Trees seriously weakened by disease or decay at a large crotch (Fig. 2), and skeleton trees which have ceased to serve communities for purposes of shade not only are frequently a blot on the landscape but may actually constitute a serious menace. Sometimes failure to appreciate the need for the prompt removal of such trees or the lack of responsibility for this work may cause serious delay in the removal of a dangerous tree. The result of this delay may prove injurious, fatal, or costly to someone.

Evergreen Failures. Coniferous evergreens may be injured by the weight of snow on branches or tree tops. When parts of trees are broken, the same treatment accorded wounds of deciduous trees may be given or may be altered as necessary. In all cases, branch stubs or rough jagged edges of wounds should be cut back smoothly. The resin coating which usually covers cut surfaces of evergreens suffices as a dressing. When trees are broken during a wind or wind-and-rain storm, the entire tree or most of it commonly falls (Fig. 1). The guying of evergreens in certain locations will sometimes prevent accidents of this type.

Trees and Utility Wires. Trees and wires both serve society in war as in peace. Adequate tree maintenance and maximum service from wire-using agencies do not represent fundamentally divergent policies. Certain conflicts between trees and wires are inevitable, however, and the results of some of these conflicts and the mechanical devices adapted to overcome or minimize them are shown in figure 8. Shade tree maintenance has benefited materially from the joint use of poles by utilities, as well as in other progressive utility programs. The almost forgotten overhead wire mazes (Fig. 9) which have been compacted (Fig. 10) and in many cases placed underground, foretell even better conditions for shade trees in the future. Placing utility wires underground, however, should not be considered a panacea. In certain instances this practice is desirable and practical, but at other times the cost to consumers would be prohibitive. Nor should it be

supposed that wires underground may be forgotten, since tree roots and wires may sometimes conflict. For the present, however, the equipment of wire-using agencies is not likely to be changed materially, and there should be opportunity for additional study of problems concerned with overhead wires and trees. During wartime, extra vigilance is necessary to insure the fullest measure of uninterrupted service from both trees and wires, and accidents resulting from the falling of weakened trees should be prevented.

The following data prepared independently by L. B. Shepherd, Division Toll Service Supervisor, New England Telephone and Telegraph Company, indicate the nature of tree troubles encountered by wire-using agencies. A total of 35 percent of toll open wire troubles is associated with trees, principally sugar maple, poplar, elm, birch, spruce, beech, and oak.

Sugar Maple—Failure occurs at the crotch, and at the time the limb is in leaf. To all appearances, the tree may be a healthy one. It is suggested that crotches of old maples be checked for decay, and that ends of limbs be examined for indications of dying branches.

Poplar—Failure occurs by trunk breaking off either at base or near top of tree, after tree has reached 8 to 10 inches in diameter.

Elm—Failure occurs in large elms at the crotch or midway in limb, probably on account of the resistance to the wind when the tree is in full leaf. Crotches should be checked as suggested under "Sugar Maple", and crotch reinforcements should be provided for those limbs considered hazardous. Experience has shown that limbs of elms are brittle, and snap easily under pressure.

Birch (White or Yellow)—Failure occurs during period of heavy wet snow. Trees become laden with snow and ice and lie over into wires.

Spruce or Pine—Failure occurs during violent wind, and trunk snaps off about 15 or 20 feet from ground line. It is suggested that attention be given to trees that are leaning (probably result of hurricane), shallow rooted, and have dying foliage.

Beech and Oak—Failure occurs when trees are leaning into wires, particularly on sidehills.

Cutting Wood for Home Use. The fuel shortage has brought an increase in the number of inexperienced persons chopping wood for home consumption. In order to accomplish the most for their efforts, persons will do well to consult their county agricultural agents and inform themselves on time-saving methods in the cutting and use of fuelwood. Careless chopping has in some instances resulted in serious damage to utility service. Fuel conservation of this type is indeed attained at a high cost in other critical materials and service. The felling of trees on wires should always be avoided, and in doubtful cases, chopping in the vicinity of wires should not be attempted. Extended fuelwood programs organized to save other types of fuel serve a valuable need if dangers of spreading the Dutch elm disease and damaging service of wire-using agencies are carefully guarded against. With certain limitations on the disposition of elm wood, as indicated elsewhere in this publication, the consumption of wood from hazardous trees may be an important supplement to the fuel conservation program, especially in cities where woodlots are not often immediately available. However, attention should be called to the fact that trees in the public way or on the boundaries thereof are the responsibility of the tree warden, and promiscuous cutting by individuals is unlawful. Disposition of the wood after a tree is cut may be arranged by the municipal officer in charge of trees.

Harmful Practices. Willful maltreatment, panacea claims, and tree magic are for the most part of historical interest only in connection with modern tree care. An informed public, the sincere efforts of the members of the arboricultural profession, and in some states the licensing of tree workers, have done much to establish the scientific treatment of tree troubles. Damage sometimes results from carelessness, inadequate diagnosis of tree defects, or the employment of inexperienced operators, and every effort should be made to shun these pitfalls.

PRECAUTIONS

Essential Considerations. Many of the operations essential to the satisfactory maintenance of shade trees can be completed by persons without specialized training. Nevertheless, certain important considerations concerning trees and apparatus and materials employed should always be borne in mind.

A person contemplating tree work would do well to inform himself concerning the nature of the tree, details of the operations involved in his plans, and the equipment and materials necessary for the work. By so doing he will more fully appreciate the significance of the completed job whether he does the work himself or employs others to do it. An excellent procedure before beginning actual operations on a tree is to make a diagram to scale showing the operations contemplated. In this way an individual will give himself the opportunity of experiencing practical problems involved and develop an intelligent plan of action. Whenever possible, attention should be directed toward corrective treatment of minor defects and the prevention of major injuries by early treatment.

Poisonous Materials. Many of the materials used for the protection of tree wounds and as sprays on foliage are poisonous, inflammable, or caustic. Utmost care in handling all materials should be exercised constantly, therefore, and all materials should be used only in accordance with directions furnished by the manufacturer. One should always be mindful of protecting other persons, animals, and property from damage resulting from operations or the use of materials. Unused materials likewise require attention and should not be stored in places, or under conditions, in which they are or may become hazardous.

Poisonous Plants. Two important woody plants associated with injury to humans are poison ivy (*Rhus toxicodendron* L.) and poison sumac (*Rhus vernix* L.) (Fig. 11), and all persons working with trees would do well to be able to recognize both of these plants in the field. Detailed descriptions and discussions of poisonous properties are available elsewhere for those interested; attention here is directed to the need for avoiding direct contact with roots, stems, leaves, flowers, or fruits — as well as the smoke arising from the burning of any of these plant parts. Injury to humans is an irritating dermatitis, the extent of which varies greatly according to the individual. Specific directions are required for any effective program dealing with ivy and sumac eradication.

Electric Current. For reasons of personal safety, as well as the protection of utility service, work on trees or parts of trees in close proximity to wires should be undertaken only by authorized persons, skilled in this particular practice. Individuals observing the need for tree work of this type should make prompt report to, or obtain information from, the tree warden or other duly designated municipal officer.

Figure 1. A fallen evergreen tree with decayed trunk. Failure in this tree blocked the highway and disrupted service by wire-using agencies. Inspection could probably have detected the trunk weakness in the decayed tree. Note undisturbed sound evergreen in foreground which was subjected to the same meteorological conditions. Photograph furnished by Boston Edison Co

Figure 2. Advanced decay in this elm and a sleet storm combined to interrupt wire service in this community. Damage by this fallen tree could have been even more serious; note proximity of dwelling house and police and fire equipment. Photograph furnished by Boston Edison Co.

Figure 3. The fungus, Polyporus versicolor Linnaeus ex Fries., fruiting on the trunk of a maple. Abundant fruiting of this fungus, which grows on dead sapwood, is an indication of extensive weakness in a tree.

Figure 4. A red maple almost completely girdled at the base by a root. Note bulging of trunk slightly above ground line, which is characteristic of this trouble. Root causing the girdling is often slightly under the surface of the ground.

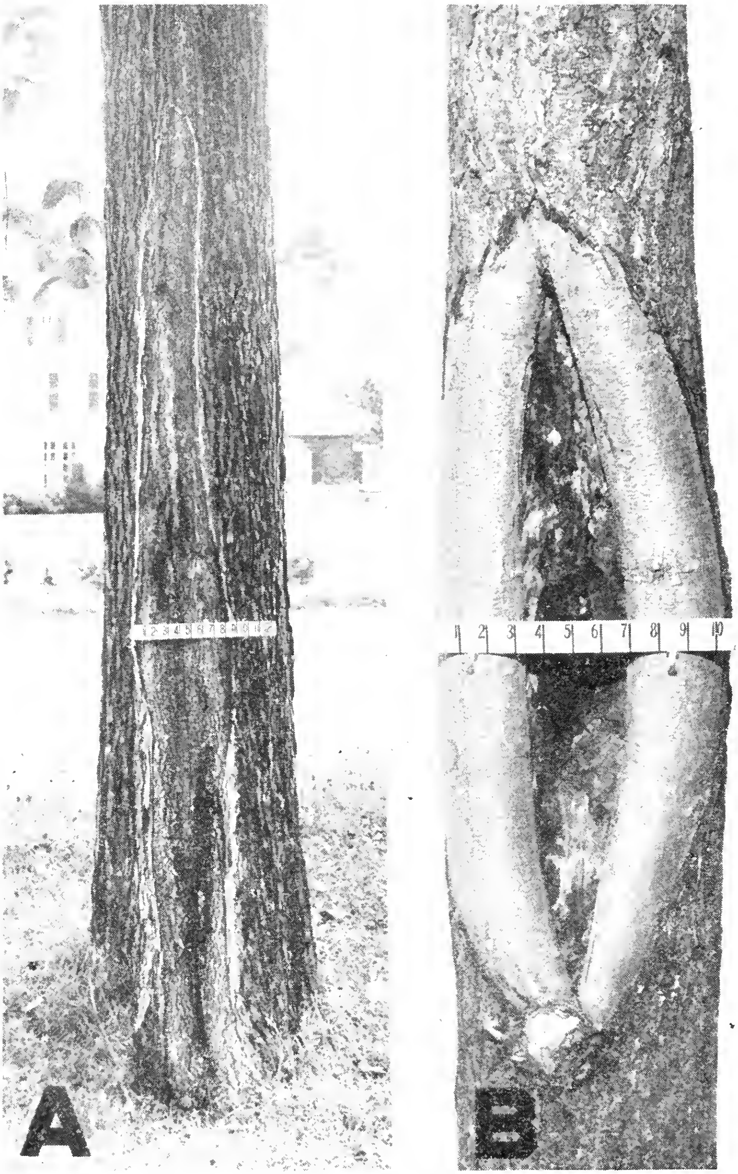

Figure 5. A. Frost crack which healed. Closing was complete, but cutting back of bark to healthy tissue and sterilization and dressing of wound were necessary to promote satisfactory wound healing.

B. A treated hurricane wound in which the bark was cut back to a smooth regular contour and shellacked. Wound dressing was applied to wood. Complete healing of the wound may be expected in such cases.

Figure 6. An elm in which a frost crack extended from a crotch down the trunk. Note repeated reopening and resultant slime-flux.

Figure 7. Tree anchorage weakened by excessive root pruning. Note cracking of soil shown in upper photograph taken well in advance of casualty shown in lower photograph.

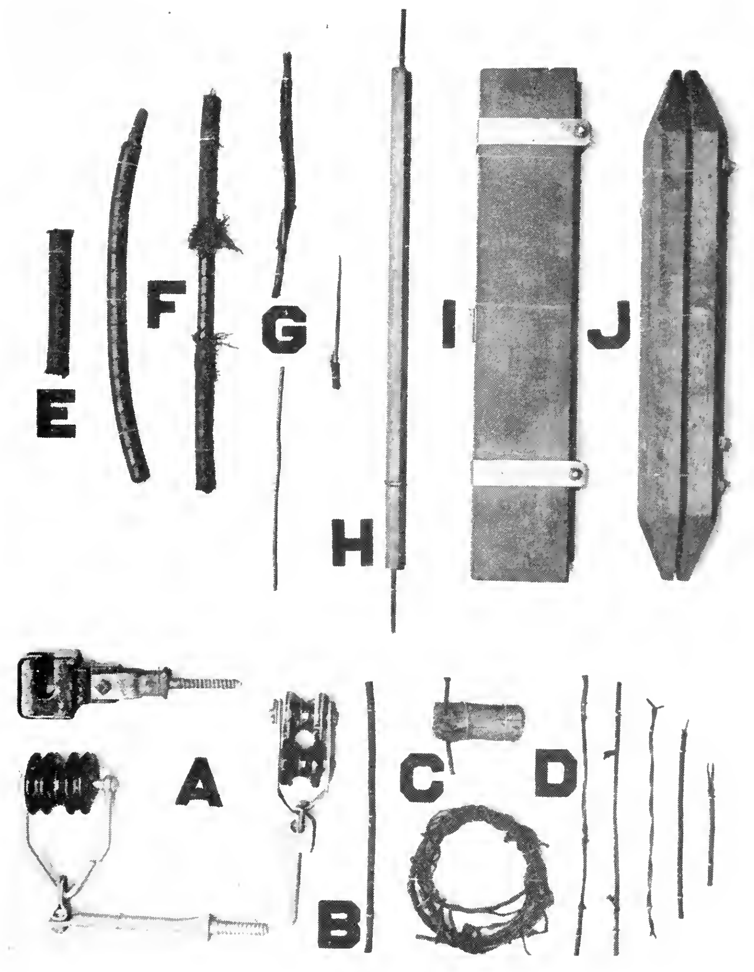

Figure 8. Tree trouble board prepared by wire-using agencies. Approximately x 1/9.
A. Electric light insulators used by light companies to protect wire from trees.
B. Telephone tree wire used for drop wire through trees.
C. Telephone wires showing abrasion from trees.
D. Effect of contact with light wire after insulation was worn off in tree.
E. Electric light tree wire before use.
F. Electric light tree wire showing abrasion from trees.
G. Electric light wire showing wear from hanging in electric light insulators.
H. Tree guard for telephone wire.
I. Tree guard for telephone cable covering cable and strand.
J. Tree guard for telephone cable covering strand only.

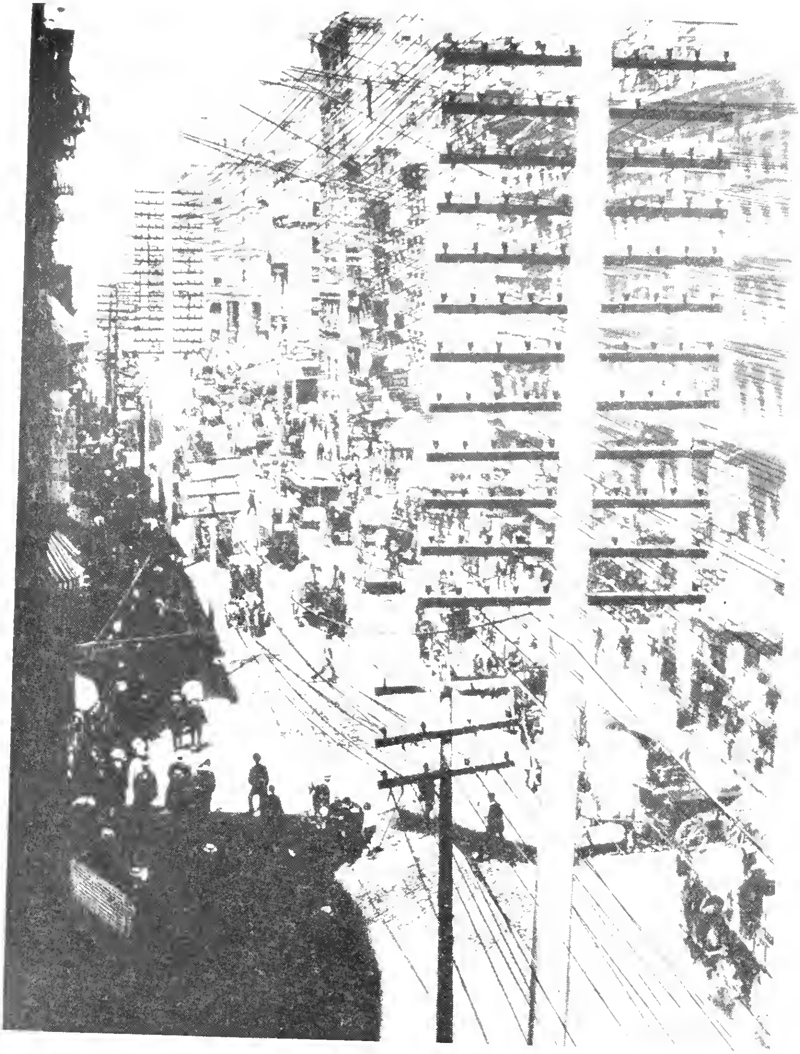

Figure 9. Add all the new telephone wires to this maze of 1887, then picture lower Broadway today! Some poles were 90 feet high, with 50 crossarms. This pole line near the corner of Broadway and Maiden Lane, New York, carried 150 wires. Today, under this same section of Broadway, there are about 30,000 telephone wires in 17 cables! Farther uptown, under the intersection of Seventh Avenue and West Thirty-sixth Street, 282 cables, containing about 560,000 wires, enter manholes from four directions. Pole lines today are fast disappearing in cities but still are used in rural districts. Reprinted from National Geographic Magazine Vol. LXXII, No. 4, October, 1937 p. 399. Photograph copyright American Telephone and Telegraph Co.

Figure 10. Today you talk over a wire; Tomorrow you'll see over one. On left is a section of cable, containing 600 wires, such as now is used for long-distance calls and network radio programs. At right is a section of the new "coaxial" cable, over which you can "see" by television as well as talk. It is only one-ninth as large as the other and contains two flexible copper tubes, with a thick wire inside of each. Waves like those of radio will carry 240 conversations at once through this cable, each at a different frequency. Other waves will carry television pictures over the same channel. Copyright National Geographic Society.

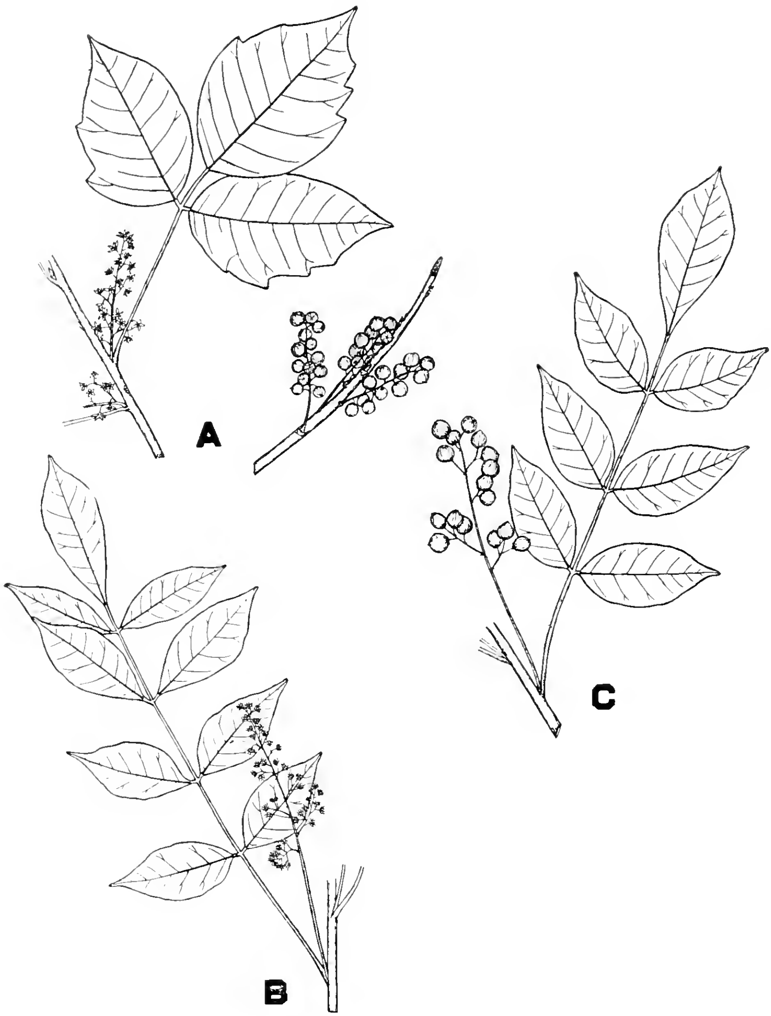

Figure 11. A. Poison ivy (Rhus toxicodendron L.), woody stem, flowers, fruit (berries), and compound leaf, consisting of three leaflets.
B. Poison sumac (R. vernix L.), woody stem, flower and 9-leaflet leaf.
C. Poison sumac woody stem, fruit (berries), and 7-leaftet leaf.

Drawn by S. J. Ewer. Approximately x 1 3.

Figure 11. D. Winter condition of poison sumac Note fruits which may persist during the winter. Photograph courtesy of R. L. Coffin.

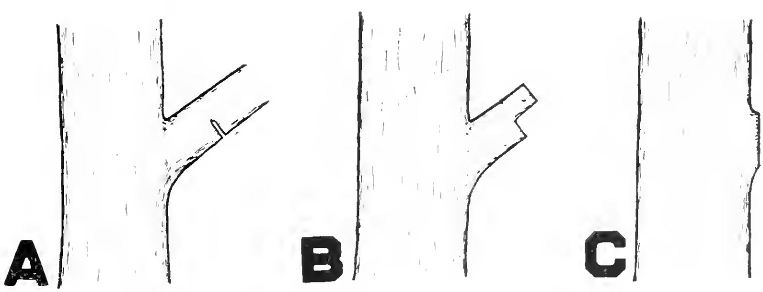

Figure 12. Safe procedure for removal of limb.
A. First cut on lower side of limb.
B. Second cut on upper side of limb.
C. Removal of stub by final cut.
Drawn by S. J. Ewer.

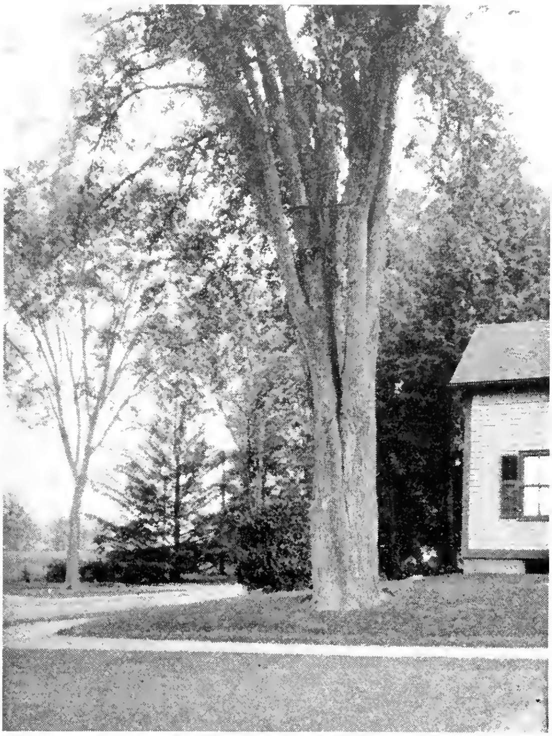

Figure 13. The earliest successful crotch bracing in the United States on the campus of Massachusetts State College, showing the now discarded practice of wrapping braced limbs with chains as well as the method of sinking end of brace in branch. In modern tree work the use of rigid bars in higher parts of the tree for direct strengthening of crotches is an improvement over the earlier method, but the principle of multiple bracing and the sinking of braces in the wood to avoid girdling are the same. The work in the tree pictured survived all tests perhaps too well, for the full crown of the tree remained intact permanently, but the tree was uprooted in the hurricane of 1938. Photograph furnished by the late Dr. George E. Stone, under whose direction the tree operations were completed

Methods, Equipment, and Materials. In pruning work, attention should be given not only to the details of removing a troublesome branch but also to the effect the necessary operations will have on the future vigor and development of the tree. Carelessly chopping a heavy branch may result in an ugly wound and permanent injury to a tree, whereas the desired removal of the branch could have been accomplished satisfactorily with a pruning saw. Special tools and supplies are sometimes necessary for operations on trees, and in recent years supply houses have listed considerable tree surgery equipment and material. However, during the war emergency, it is futile to indicate detailed operations for special tools, since in most cases individuals will have to rely on their ingenuity to make use of any tools and equipment at their immediate disposal. The sterilization of the implements used in tree operations with alcohol is an added precaution against spreading decay organisms and infectious disease fungi. Also, freshly made cuts in which fungi are present may be sterilized with a water or alcoholic solution of mercuric bichloride. especially if the wound dressing or paint to be applied later does not possess antiseptic properties. These operations may prevent primary wounds from developing into extensive injuries such as cavities which require special study before satisfactory treatment can be attempted.

For similar reasons, when bolts, braces, and guys are installed in trees as mechanical aids for support, the parts contacting the wood may be dipped in asphalt or some other suitable material to check the development of fungi. When a brace is to be installed in tree branches, a hole somewhat deeper and slightly under the size of the brace may be bored, to provide for the accumulation of sawdust and enable the brace to fit snugly within a decay-resistant groove. If the completed job is not waterproof, the operations may have done more harm than good. A leak which develops around a bolt may ultimately weaken the entire support.

Foresight vs. Hindsight in Tree Management. Practices and remedies based on rumors and legends should be avoided in favor of approved methods. Almost daily, correspondents belatedly seek advice on the repair of injurious cures they inflicted upon trees from intuition without preliminary consideration of the work they wished to undertake or the nature of the living trees at their mercy.

A record of completed and proposed tree work, including lessons learned by experience, will be a valuable aid in checking results and serve as a reminder of uncompleted jobs. The record will also call attention to the need for repainting certain wounds and giving other supplementary treatment from time to time. No list of suggestions could provide for all of the problems which will be encountered in individual tree operations, but by intelligent planning many costly disappointments may be avoided.

TREE PROTECTION AND IMPROVEMENT PRACTICES

Although the variety and sometimes the extent of defects found in trees during these studies might appear to be cause for alarm, any exaggerated fears of a treeless future should be allayed by the predominance of relatively sound and vigorous trees. Moreover, many of the defects can be treated with appropriate remedial measures.

Municipal Trees Planted on Private Property. In the General Laws of Massachusetts, provision is made for the use of public funds for planting trees on private property under prescribed conditions. Chapter 87, section 7 reads:

"Towns may appropriate money to be expended by the tree warden in planting shade trees in public ways, or, if he deems it expedient, upon adjoining land, at a distance not exceeding twenty feet from said public ways for the purpose of improving, protecting, shading or ornamenting the same; provided, that the written consent of the owner of such adjoining land shall first be obtained."

Some tree wardens who have availed themselves of this provision of the law report satisfactory results. No definite recommendations on the desirability of planting trees on private property can be furnished, however, since conditions vary widely in different communities. It sometimes happens that in areas where narrow tree belts obtain, dwelling houses have little, if any free space as frontage. Nevertheless, it would be well for tree wardens to explore all possibilities for planting on private property in order to improve local tree conditions as far as practicable.

Disease and Insect Control. It is not feasible to give control practices in detail for the individual fungus diseases and insect pests observed. Diagnoses made from specimens submitted to the Experiment Station will be reported whenever the cause for the trouble can be definitely ascertained from laboratory examination. Standard spray programs for the protection of foliage constitute the minimum pest control measures that should be accorded trees.

Physiological Troubles. Physiological troubles of trees may be revealed by the presence of small leaves or early yellowing and loss of foliage. Progressive weakening, following disease, repeated insect infestation, and faulty transplanting often result in certain physiological disorders. Inadequate food and water relations are also common sources of trouble.

Compensation for lack of water during extended periods of drought may be made by adequate watering of the soil about tree roots. If necessary, holes may be drilled as in the application of fertilizer discussed below. Plant foods may likewise be made available by addition of fertilizer to the soil about the feeding roots, the amount required being dependent upon individual cases.

A satisfactory technique for introducing fertilizer into the soil includes the drilling of holes about 18 inches deep and 2 feet apart, in the ground approximately under the limits of branch spread, or closer in the case of small, round-headed trees lacking extensive feeding roots. The fertilizer is then inserted in the holes, leaving the upper two inches for the replacement of soil. In determining the location of feeding roots of spiry trees, holes should be drilled beginning at a distance about half the height of the tree away from the trunk and extending in concentric circles to the limits of the roots.

The value of decaying organic matter, such as well-rotted manure worked into the soil at the rate of 15 to 20 cubic feet to 100 square feet of soil, should not be overlooked in choosing a satisfactory general utility fertilizer. Unfortunately local conditions may often make its use impracticable. However, when manure is used it should be mixed thoroughly with the soil or a manure and soil mixture should be introduced into holes in the same way as prepared fertilizers. At times, roots under turf or in hard-packed soil may not be satisfactorily reached by ordinary methods and aerating the soil in a cultivation program may be advisable. Plowing the surface of the ground about a tree permits many advantages when this practice is feasible. Fertilizers such as nitrate of soda, at the rate of 2 to 5 pounds for a medium-sized tree, and sometimes small quantities of lime may be applied in the spring on the surface of plowed ground. Trees, such as oaks or black and red spruce, which require an acid soil, are to be excepted.

Raw bone meal is a good fertilizer for most trees and may be applied either on a plowed surface or in drilled holes. It becomes available slowly and appears to do no injury even when used in large quantity. In applying all nutrients care should be exercised not to overfertilize trees, else root burning may result and more harm than good be accomplished From the fertilizers applied to he soil, only those substances which are water soluble and can be absorbed by the root hairs will have direct nutritional value. Hence, the presence of water is always necessary in any successful fertilizing program. The retention of water and other substances in the soil may be facilitated by the application of mulches. Such practice is of particular importance in the case of evergreens.

Treatment of Wounds. Wounds on limbs and trunks of trees occur in a variety of shapes and sizes. Those which result from the fracturing of a branch usually have irregular and jagged margins. All wounds which can be shaped so that the longer axes are parallel to the grain of the wood and which may be brought to points at the extremities, are likely to heal more satisfactorily and to appear less ugly than wounds not so treated. Final cuts of the wound margin should be made so as to provide opportunity for callus growth (Fig. 5, B) and for drainage of water.

When the outline of the surface to be treated has been definitely determined, all rough and loose edges of bark should be removed with a sharp chisel, and shellac applied with a small brush. The shellac will prevent drying out of the narrow exposed moist layer of the inner bark. When this step has been carefully completed, the wood surface of the wound should be made smooth and treated with creosote, creosote oil, or other sterilizing agent; and with coal tar, asphalt or other materials for protection. Creosote is inflammable and should not be permitted to come into contact with an open flame. The creosote should be applied only to the cut wood surface, with particular care to avoid the living inner bark previously covered with shellac.

Good wound dressings or paints are possible substitutes which may be used in a single application provided the precautions previously outlined are observed. Asphalt without creosote is an excellent protective covering for wounds. The necessity of applying it hot doubtless explains why it is not more widely used. An emulsion of asphalt and water is obtainable commercially and the use of this preparation eliminates the necessity for heating. This material may be applied in the same way as wound paint. The water soon dries, leaving an asphalt covering.

The application of tar mixtures and creosote may cause severe injury to certain trees including magnolias, tulip-trees, and ornamental *Prunus* species. For these, other treatment is advisable, even though less permanent in character, and the following sterilizing and protective materials are sometimes used: liquid wax, shellac, corrosive sublimate (bichloride of mercury), copper sulphate, spar varnish, grafting wax, good commercial Bordeaux paste, Bordeaux powder mixed with raw linseed oil, and water glass (sodium silicate).

In applying all protective coatings, care must be taken not to cover the uninjured bark about the wounds. Frequently, recoating of treated surfaces may be necessary after a year's time, and blistering, cracking, or checking should be corrected as soon as detected. Careful attention to these details may preclude additional serious injury. In all cases, individuals contemplating the use of materials on trees should inform themselves thoroughly concerning the nature of these materials and their proper handling, including the need for precautions against possible injury to persons and property.

Small wounds on slender branches do not ordinarily require protection but may be treated on valuable trees as a precautionary measure. When pruning operations include so many small branches that treatment of all cut surfaces is impossible, a safeguard for prompt healing is the careful use of a sharp hand or pole pruner. In using an ordinary hand pruner with a curved blade, especially on surfaces which are not to be treated with a protective covering, care should be taken to hold the pruner so that the supporting base may bruise only the discarded twig. Pruning hooks should be used only with considerable caution.

In making secure one's position while treating wounds in remote parts of trees, it is often necessary to resort to the use of ropes. Experienced workers use ropes extensively both while pruning and while treating tree wounds. The amateur may frequently find that he is able to remove branches without the aid of ropes, but they may be necessary to establish a safe position before engaging in extensive wound treatment activities. The wearing of spurs, however, is never advisable in operations where the tree being treated is to be retained.

Pruning. Pruning is an important part of any tree improvement program and may be accomplished at almost any season of the year when practicable. In spring, when tree growth is most active, wounds inflicted during pruning tend to heal more rapidly than at other seasons. However, bleeding is most copious at this time, and loss of sap may somewhat weaken the trees as well as prove a nuisance along streets and highways. For these reasons, excessive bleeders, such as birch and maple, should always be pruned later in the season. Pruning when the tree is in full leaf also has advantages in that dead and weakened parts are then more obvious; and street and park trees are often pruned in winter when spraying and other tree work programs are less pressing.

Whether the pruning work to be accomplished is simple thinning, extensive trimming, topping, or pollarding, the technique of removing branches should receive careful attention. On large limbs the first operation should be a cut made with a saw on the under side of and somewhat less than half way through the limb at approximately one foot from the ultimate pruning point (Fig. 12, A).

This should be followed by a cut on the upper side of the limb about two inches farther out than the lower cut. Cutting with the saw should be continued until the limb falls (Fig. 12, B).

A third cut made at the ultimate pruning point will remove the stub and leave a clean cut surface of minimum size for sterilizing treatment and at the same time promote a rapid callus growth (Fig. 12, C).

An attempt to complete the cutting in one operation on the upper side of the branch will most frequently terminate unhappily in an ugly enlarged wound surface which will not callus over but will encourage slime flux and defy satisfactory later treatment.

Following storms, the prompt pruning of broken branches is essential in treating damaged trees. A saw which makes a wide cut is the best implement to use in removing large branches. A strong sharp knife, a mallet, and a chisel will complete the necessary instruments for removing accessible limbs. Bark or wood which is splintered or loosened should also be removed with a sharp cutting implement and the same protection against infection should be employed as in the case of wounds.

Doubtless there will be instances in which all efforts to restore symmetry to a storm-injured tree by pruning will fail. In such cases, severe pruning of the entire top of the tree, or pollarding, may be the best solution to the problem. Most trees respond to pollarding in some degree, and certain trees, like willows,

respond readily. In the course of time a nearly normal tree symmetry may be developed by gradually reshaping the outline of profuse dense growth, and later the tree's symmetry may be further improved by grafting if this practice proves necessary. The result will commonly be the production of a dense head growth. To a limited extent, this growth is often an effective contribution to the landscape.

Cavities. Certain general suggestions for the repair of cavities have already been indicated. In special cases, complete treatment involving excavation, sterilization, bracing and filling may be desirable, but it is most doubtful whether an inexperienced worker is ever justified in undertaking to complete the entire series of operations independently. In many cases, cavity enlargement can be checked by removing the obviously diseased wood and sterilizing and protecting the exposed surfaces. It is almost impossible to eliminate all infected wood, but debris and decayed tissue should be removed so as to expose a reasonably sound and smooth wood surface which can be treated with antiseptics and protected with wound dressing as already indicated. Careful consideration should be given to the matter of the ultimate shaping of cavities in order to prevent the accumulation of small reservoirs of water.

Mechanical Support. Any one of a variety of factors may indicate the need for supplying additional mechanical support in trees. Specifically, attention has been directed toward the following conditions of a tree and the environment which make bracing advisable: decay, split crotches, weakened sharp-pointed crotches, borer infestation, injured or pruned roots, poor or limited shallow root systems, profuse top growth, proximity of damageable property, exposure to strong wind, or loss of sheltering structures.

Considerable progress has been made recently by professional tree workers and students of mechanics in the matter of bracing trees. Experimentation and experience have pointed out certain errors in early work (Fig. 13).

The use of steel rods as rigid braces with or without washers and nuts is commonly termed bolting of trees. In cases where parts of a tree must be drawn together for bolting, the hole bored for a prescribed screw rod should be larger than the screw rod. Therefore, washers and nuts must be used on both ends of the rod. For other purposes it is evident that holes drilled for screw rods should be rod size or smaller. Holes smaller than rod size should be drilled when washers and nuts are not used on ends of screw rods. In this case dependence is placed upon the grip of the screw rod in the self-threaded channel. When the size of the hole drilled to receive the screw rod is identical with the size of the rod, washers and nuts should be used on both ends of the rod. Screw rods serve in crotch bolting, holding limbs together or apart, and cavity bracing. Also, as "lip bolts", these rods draw together a long split or frost crack in trunk, branch or cavity. Specific conditions will determine the number and location of screw rods needed to insure the relative safeness of trees.

Steel cable instead of rigid rods is often used for bracing trees. A simple method of cabling employs the fastening of a lag hook or eyebolt into each of the two limbs forming a crotch so that the hooks or eyes face each other. The hooks or eyebolts are then tied with steel cable. Where lag hooks are used, provision should be made so that a final quarter turn will make the cable secure.

When trees require additional structural support, guying may solve the problem. In such cases wires are appropriately affixed to the tree and connected with four strong posts set firmly in the ground on the north, east, south, and west sides. If the guying is temporary, broad bands of leather or other strong material are sometimes wrapped around the tree and supporting wires attached.

In the case of permanent guying, however, two eyebolts may be placed on opposide sides of the tree trunk, one about six inches above the other and two wires fastened to each.

Bridge Grafting. An injured part of a tree to be bridged by a graft should receive as preliminary treatment the same protection given any other wound. In the spring, at which time the grafting is to be performed, the wound should be inspected and the adjacent bark cut back evenly with a heavy pruning knife to provide the wound with edges of tightly fitting, healthy tissue.

The young shoots or scions to be used in bridging the wound should be in a healthy condition but completely dormant. To insure dormancy in scions, pruned from the tree being treated or a similar one, it is advisable to cut twigs about the diameter of a lead pencil to the desired length before the buds swell in the early spring and store them under conditions which will prevent drying out. A good method is to bury them on the north side of a building where warming of the soil in spring is delayed. A protective covering wrapped about them will prevent direct contact with the soil and a board over all will insure against water soaking of the scions in the event of seepage into the ground during heavy rains.

Immediately prior to their use, scions should be sharpened or beveled by long sloping cuts in order to form thin wedge-shaped ends which may be pushed well under the bark without noticeably separating it from the growing layer. The entrance points for scions are provided by extending cuts vertically for about two inches from the wound at each point where a scion is to be inserted. The cut bark at the upper end of the wound should then be raised slightly and one end of the prepared scion slipped into place. The other end of the scion is then inserted in similar fashion into the cut bark at the lower end of the wound. For most satisfactory results, the scions should be approximately in line with the grain of the wood and of sufficient length to arch somewhat over the bridged area. Small brads will hold the ends of scions in correct position, and liquid wax freely applied to the upper and lower wound edges and to the edges of the attached scions will prevent drying out. The number of scions required will depend upon the size of the area to be bridged.

Disposal of Stumps. Two general methods for the disposal of tree stumps may be employed. The stump may be removed entire from its site by aid of root pruning and the use of heavy apparatus, or the stump may be destroyed in place by burning or other means. If the former method is used, there may be certain advantages to retaining a portion of the butt for purposes of leverage. Details of this method are omitted here, however, since the use of heavy apparatus requires the services of experienced operators.

The destruction of a stump in its site, when it cannot be readily disposed of otherwise, may be accomplished in a reasonably simple manner after completing certain necessary preparations. The part of the stump above ground should be reduced as much as possible by cutting off the trunk as near to the ground line as convenient. Generally, in the case of a storm-uprooted tree, this operation will be most satisfactorily completed by working on the tree without attempting to free it from any position in which it may have become securely fixed. Upright stumps may present some difficulty, while in the case of uprooted trees the disposal is already partly accomplished. Having eliminated much of the stump above ground, the next step is to reduce the underground stump. Removal of the soil so as to form a circular trench, followed by progressive digging toward the ball of the root, may consume time, but careful attention to this detail is essential for later satisfactory progress.

Attention should next be given to the matter of severing any remaining roots holding the stump in place. At this point the stump without root attachments should be in such relationship with the ground that except for its weight it could be readily removed from the hole. The closely packed soil about the roots may be removed with a pickaxe or washed off with a strong stream of water when this facility is available. The use of water, even if dependence has to be placed upon a heavy rainstorm, has advantages, particularly if local conditions permit good drainage.

The root ball, free from soil, should then be allowed to dry thoroughly and any parts of it which can be chopped off should be eliminated. In this way the stump remaining for ultimate destruction can be still further reduced, and any axe blows which fail to sever parts of the root stump completely enough for removal will not be in vain since they will aid in the final destructive process.

The appearance and condition of the stump at this stage in the operations should determine whether additional openings in the form of holes bored with an auger are necessary before the application of kerosene. Intermittent applications of kerosene daily allowing time for adequate penetration through entrances cut and bored near the top of and throughout the stump, should be as numerous as the varying conditions may require. When penetration with kerosene is reasonably complete, dry rubbish, placed over and about the stump, should be ignited. The stump will then be either partially or completely consumed, depending upon the thoroughness of preparation.

This method of destroying stumps may be curtailed or elaborated according to the results desired. Sometimes the only objective may be the reduction of size to permit burial of the stump in its original site. In other cases complete destruction or reduction of the stump to a size which will permit easy removal is necessary. It is obvious that this discussion is concerned principally with the destruction of individual stumps in small-scale operations by a reasonably safe method. Large-scale operations may employ temporary chimney construction, forced draft burners, or explosives. The method outlined is of use primarily to persons without expensive equipment or knowledge of machinery and construction. The chief penalties are the time consumed and the extra work necessary in preparation.

Detecting and Reporting Defects. During the summer season, dead, defoliated, and injured trees are often easily spotted by the absence, sparseness, or discoloration of leaves. At other seasons signs of injury are less conspicuous, but fractured limbs and some other injuries may be more clearly seen because of the absence of foliage. The weight of snow and ice on branches sometimes causes injury to trees, and prompt treatment or removal of injured parts should prevent tree injuries from becoming injuries to persons or property.

The extent of damage to utilities' wires and other property resulting from falling trees indicates the need for detecting badly weakened trees before they collapse. It may be pointed out that there is need for all utilities to keep their lines under inspection and arrange for the immediate removal of any hazards which threaten them. Intelligent cooperation by the public in reporting to their municipal tree departments all dangerous trees, will aid in preventing service failures and destruction of scarce materials.

CONCLUSION

Safe Trees the Minimum Requirement. In former years federal funds for public works supplemented local appropriations and permitted many communities to give needed care to municipally owned trees. More recently, war activities have absorbed the personnel previously employed in this work to such an extent that even when additional appropriations for tree work are available, it is not always possible to have the work completed. In spite of obstacles, however, safe trees must be the minimum requirement for municipal tree programs.

Responsibility and Organization. Unless some way can be found to distribute more adequately the responsibility for tree work, the number of trees neglected over one or two years may increase to a point where no amount of community organization can solve the problem. Already an increase in wire interference by trees has been reported by the public utilities. It is essential that civilian and military workers be protected while travelling in the public way; it is also essential that the communication and power lines be maintained with the least possible disruption. Public utilities are keenly aware of their responsibility in maintaining vital service lines and are prepared to do their part in eliminating tree hazards. Their supplies for replacements and new equipment are critically limited. Repairs are costly and preventable accidents are wasteful. Many tree injuries can be treated and many impending tree accidents can be prevented. Civilians have organized themselves into groups for protection against air raids and invasion and, in the light of mounting tree casualties and resultant property damage, it would be well to provide for tree protection as a supplement to the civilian defense program.

Know your Tree Warden. Massachusetts is especially fortunate in having a tree warden in every community as a key man about whom to rally in this important activity. Advance information concerning a weakened tree may save a life, a life line, and a tree. Tree wardens may further enhance their already distinguished service throughout Massachusetts by organizing corps of civilian inspectors, and supervising their activities. Such a corps might well consist of representatives from the following organizations: Massachusetts Horticultural Society, Garden Club, Women's Club, Rotary, Kiwanis, Massachusetts Forest and Park Association, Massachusetts Safety Council—in fact, all groups interested in civic affairs; in addition to representatives from the wire-using agencies, such as power, municipal light, telephone, police and fire alarm telegraph. Without doubt, these organizations will aid the tree warden by nominating or recommending qualified and interested civilians to serve with and assist the warden in processing such a protection program. The public can cooperate effectively by discovering and reporting defects in trees to the local tree department.

MY TREE WARDEN'S NAME ....

STREET ADDRESS..

TELEPHONE NUMBER..

THE DUTCH ELM DISEASE

Since 1930, when the Dutch elm disease caused by the fungus, *Ceratostomella ulmi* (Schwarz) Buisman, was first discovered in the United States, all persons interested in our shade trees have become increasingly alarmed as the number of elms known to be affected has steadily mounted. As the name implies, the Dutch elm disease was first observed in the Netherlands; and, since its discovery in 1919, thousands of elms in European countries have been killed. The disease exists throughout the extensive range of climatic and soil conditions included in the Netherlands, France, Italy, Austria, Belgium, Switzerland, Germany, Poland, Czechoslovakia, Balkan States, and Great Britain. The disease is widely distributed in England but has not as yet been found in Scotland.

In both Europe and North America, the only continents where the disease has been observed, elms and trees of the closely related genus *Zelkova* are apparently the only hosts upon which the disease occurs in nature. A few species of elms are reported to be resistant, but none is known to be immune; and the American elm (*Ulmus americana* L.) is very susceptible.

From 1930 to 1932 the known cases of the disease in America were limited to less than a dozen trees in Ohio. Later the disease was found in the mid-Atlantic States and southern New England. Elms in Massachusetts were first known to be affected in 1941 when one diseased tree was found in the town of Alford, in Berkshire County. In 1942, six diseased trees were found in the State: three in Egremont, one in Great Barrington, one in Westfield, and one in Sheffield. These trees were destroyed immediately, and in order to further protect disease-free elms, concerted effort has been directed toward the prompt disposal of all freshly cut elm wood. This is the most practical control that can be employed effectively in checking the increase in population of bark beetles which spread the causal fungus. Since the fungus is virtually a prisoner within an affected tree, it cannot spread significantly except as it is carried from a diseased to an uninfected tree by a vector. The best evidence indicates that the smaller European elm bark beetle (*Scolytus multistriatus* Marsh.) is the principal carrier insect. This insect invades the bark of weakened trees or freshly cut elm wood, where eggs are laid in galleries engraved between the bark and the wood. Upon emergence, beetles feed for a short period of time on healthy elm twigs and in this manner may spread the disease to previously healthy trees if the feeding beetles come from galleries in which the fungus is present. At this writing (December 1942), the beetle is known to occur in Springfield, West Springfield, and Westfield in Hampden County, and widely in Berkshire County, in addition to the originally known eastern Massachusetts infestation which now includes most of the area east of Worcester County. Possibly the native elm bark beetle (*Hylurgopinus rufipes* Eich.), which is generally distributed in Massachusetts, may also spread the disease. If so, the prompt disposal of cut elm wood is doubly necessary.

Therefore, all agencies and individuals whose work brings them into contact with freshly cut or drying elm wood, which is highly attractive to bark beetles, are urged to dispose of this wood promptly by burning, unless there is complete assurance that the bark will be removed immediately after the wood is cut. Tree wardens, foresters, arborists, fire wardens, highway departments, state departments, and public utilities have cooperated generously in aiding in this practical method of protecting disease-free elms. As in the case of all fungus diseases and insect pests of plants, however, unbroken continuity of the program is most essential. Experience has shown the interruption of investigational and control programs to be a costly mistake. The elms of Massachusetts are a priceless possession of all the people of the Commonwealth.

THE DUTCH ELM DISEASE

Fig. 1. Elms in a Massachusetts town.

The Dutch Elm Disease—caused by the fungus, *Ceratostomella ulmi*, and spread by bark beetles—menaces our Massachusetts elms.

Widespread in Europe since its discovery in 1919.

Known in the United States since 1930, following the importation of fungus and carrier-beetle infested elm logs from Europe—1929 to 1934.

Found in N. J., N. Y., Conn., Pa., Md., Va., W. Va., Ind., Ohio,

MASSACHUSETTS — 1941.

Fig. 2. The street in figure 1, as it would appear without elms.

64,468 known diseased elms have been destroyed in eradication programs to September 1942.

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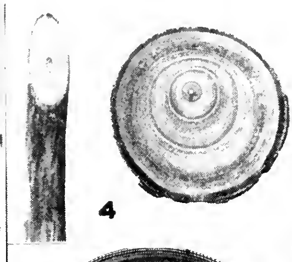

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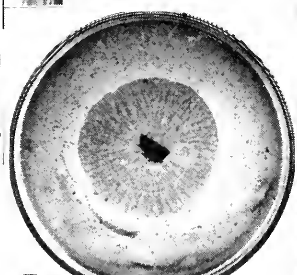

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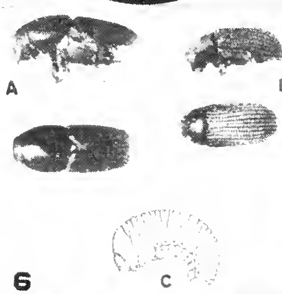

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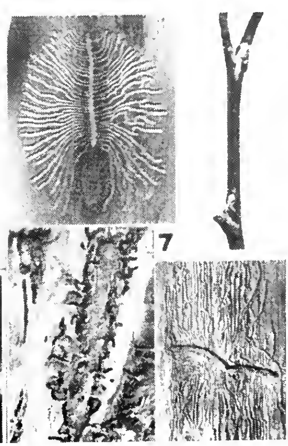

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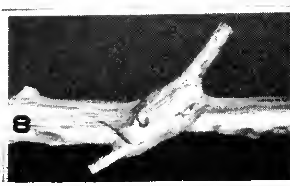

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Fig. 3. Elm affected with the Dutch Elm Disease.

Fig. 4. Streaking of infected wood.

Fig. 5. The fungus in culture.

Fig. 6. A. Smaller European bark beetle.
B. Native bark beetle.
C. Larva or grub.
(All greatly enlarged.)

Fig. 7. Work of carrier beetles. (Somewhat reduced.)

Fig. 8. Natural graft of elm roots. (Photographs from Mass. Exp. Sta. Bul. 343. Figs. 3 and 8 furnished by Division of Forest Pathology, U.S.D.A. Fig. 6 from Cornell Ext. Bul. 290.)

Symptoms of the disease include: Wilting, curling, yellowing, and early falling of leaves; Brown streaking of infected wood.

Trees may die suddenly or gradually.

A wood-staining fungus living in the water-conducting channels causes the disease.

Death of trees results from a toxin produced by the fungus.

Trees affected with Dutch Elm Disease may appear similar to elms affected with other wilt diseases—

Therefore, laboratory study of wood showing streaking is necessary to prove which disease fungus is present.

The smaller European and native elm bark beetles serve as carriers of the fungus.

The beetles engrave breeding galleries in weakened trees and later the young emerge to feed on tender green twigs.

Other means of spread include direct contact between diseased and healthy trees — natural grafts of roots and branches.

All known diseased elms are being destroyed.

The final goal of the eradication program is the protection and preservation of disease-free elms.

The public is urged to cooperate by sending specimens from the wilted parts of trees to —

THE DUTCH ELM DISEASE LABORATORY
MASSACHUSETTS STATE COLLEGE, AMHERST, MASS.

MASSACHUSETTS
AGRICULTURAL EXPERIMENT STATION

BULLETIN NO. 398 JANUARY, 1943

Annual Report

For the Fiscal Year Ending November 30, 1942

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

MASSACHUSETTS STATE COLLEGE

AMHERST, MASS.

MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION

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YOURGA, FRANK, Horticultural Manufactures
ZATYRKA, IRENE E., Pomology

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*In charge †At East Wareham ‡At Waltham §With U. S. D. A. ¶On Military Leave.

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ANNUAL REPORT OF THE MASSACHUSETTS AGRICULTURAL EXPERIMENT STATION—1942

DEPARTMENT OF AGRICULTURAL ECONOMICS AND FARM MANAGEMENT

A. H. Lindsey in Charge

Competitive Factors Influencing the Supply of Market Milk and Cream in Massachusetts. (A. A. Brown and Abigail Stone.) Bulletin 389, the last of three bulletins based on the Springfield–Holyoke–Chicopee Milkshed, was published in 1942.

The organization of production and distribution of sales throughout the State are now being studied in relation to the program of the Massachusetts Division of Milk Control.

Transportation Requirements of Rural Communities in Massachusetts. (A. A. Brown and Abigail Stone.) A study of the amount of trucking necessary for the movement of grain to farmers in the Amherst–Pelham area is near completion. One cause for excessive mileage is the frequent buying in small amounts by many farmers. Much time and probably much mileage could be saved if farmers would place their grain orders monthly and take at one delivery quantities up to the permissible mileage of the handler's truck. This sort of arrangement would reduce stops by 50 percent and result in an average delivery of .48 tons per mile. Comparison with mileage under actual conditions was not possible because some operators kept neither trip nor mileage records. Study of farmers' buying practices indicates that worthwhile reduction in mileage could be accomplished by fully utilizing handler's equipment.

Crop and Livestock Enterprise Relationships. (C. R. Creek.)

Results of Pasture Improvement Practices. Detailed grazing records were kept for the 1941 season, in connection with a record of milk production, barn feeding, and pasture treatment. Acreage of pasture ranged from 10 to 113 acres per farm with an average of 34 acres. More intensive improvement practices were applied to the small areas. Size of dairy herds ranged from 8 to 45 cows per farm with an average of 24 head. The length of pasture season was variable, chiefly because of drought in late summer, and ranged from 65 to 164 days with an average of 121.

Results from the grazing of these pastures were calculated in pounds of 4 percent milk, number of cow-days, and tons of green forage. For the relatively short season of 1941 an average of 2017 pounds of 4 percent milk was produced from each acre of improved pasture. The range per farm was from 313 to 6648 pounds per acre. Cow-days of grazing ranged from 22 to 152 on these farms with an average of 74 per acre. Production of green forage was calculated as an average of 2 tons per acre with a range from 0.5 to 3.0 tons per acre per farm. Returns for individual fields on these farms varied more widely than the range given for averages by farms.

Improved pastures consisted of annual crops, Ladino Clover, mixed clover and grass, and permanent grassland. Returns were highest for Ladino Clover pastures with 3,044 pounds of milk, 84 cow-days, and 2.7 tons of forage per acre. Clover and grass pastures ranked second, followed by annual pasture crops and permanent pastures. Returns were also calculated by types of treatment, but the variation was slight.

Labor-Saving Methods and Practices on Massachusetts Farms. (C. R. Creek.) An outline has been prepared to apply the results of previous research on labor-saving practices to the production and harvesting of vegetable crops on small farms. Inexpensive and homemade adaptations of labor-saving equipment are recommended for these farms.

Comparative Costs of Producing Corn and Grass Silage. (C. R. Creek.) Preliminary tabulations and calculations have been made of various items in the cost of producing corn and legume-grass silage on dairy farms in the Connecticut Valley counties. Cash costs of growing and harvesting corn for silage ranged from less than $1 per ton on a farm with no hired labor and no fertilizer expense to $5.06 per ton on a farm where machinery was hired for all growing and harvesting work and all labor was hired. Total costs were much higher and ranged from $4.93 to $9.13 per ton. Total costs included such non-cash items as family labor, depreciation, interest, and the value of manure. The acreage of corn for silage ranged from 3 to 21 acres per farm with a total production of 20 to 200 tons. Yields ranged from 5 to 16.5 tons per acre.

Cash cost of legume-grass silage ranged from $2.37 to $3.60 per ton and total costs from $5.30 to $9.45 per ton. Acreage of the various crops ranged from 2.5 to 40 acres per farm and yields of grass silage were from 3.8 to 8 tons per acre. Small acreages of oats used as a nurse crop for clover seedings were ensiled on a few farms. Cash costs ranged from $2.55 to $4.53 per ton and total costs from $5.90 to $10.69. Yields varied between 6 and 10.5 tons per acre of oats for silage.

Loan Performance on Low-Income Farms in Massachusetts. (C. R. Creek.) Data and information have been obtained from the farm plans for Farm Security Administration borrowers in Franklin, Hampden, and Hampshire counties. Tabulations have been made by counties for cash-crop and for livestock farms. Preliminary observations indicate that the rate of repayment of loans has been much higher on the cash-crop (onions, tobacco, and potatoes) farms than on the dairy and poultry farms. A small number of the latter have been liquidated at public auction to repay the Farm Security Administration loans.

The chief reason for loans to cash-crop farmers in the Connecticut River Valley was the loss of crops in the flood and hurricane of 1938. Low prices for crops and low yields in earlier years were responsible for the deplorable credit situation of many small operators. Increasing the size of business from a part-time or subsistence level was the reason for many livestock loans, particularly on poultry farms. Some of these operators have now returned to a part-time farm business and are working in industrial plants in nearby cities.

DEPARTMENT OF AGRONOMY

Walter S. Eisenmenger in Charge

Tobacco Projects. (Walter S. Eisenmenger and Karol J. Kucinski.)

Brown Root-Rot of Tobacco. In the experiment to determine the effect of preceding crops on tobacco it was found that tobacco, artichoke, and sunflower, as well as fallow, were beneficial as contrasted with such crops as corn, sudan grass, and sorghum, which in all cases seemed to have a deleterious effect on yield.

The crops preceding tobacco were planted at three different times: the first, early; the second, thirty days later; and the third, thirty days later than the second. The earliest planting was completely mature; the others matured to a lesser degree. The earliest planting developed more lignin than the others. These plants were permitted to stand and become thoroughly dehydrated by subsequent freezing and thawing.

Where the individual plants were of the type that prevents the growth of weeds —shade producing plants—the yield of tobacco increased after the late plantings. In plots of small plants, such as barley, rape, and rye, the weeds in late summer intrude and to a degree vitiate the results.

There is no evidence, however, of a better quality of tobacco grown after immature plants. This is not entirely new, for it is often the case that larger tobacco plants do not cure as well as smaller tobacco plants.

Tobacco Experiments with Application to Soil of Commercial Organic Materials. Different types of carbon compounds were applied to the soil to study their effect on the yield of tobacco. Because of prohibitive cost, there are not many such compounds that can be used; but cane sugar, starch, dried skim milk, and charcoal were each applied to duplicate plots at the rate of 100 pounds per acre. No decided differences were noted in the tobacco although the check plots receiving no additions of carbon were low in yield and crop index. The charcoal caused more rapid growth in the early season, probably because of the more abundant absorption of heat by the darker color induced, and also gave the highest yield, suggesting the possibility of its use in early spring for frames where seedlings are grown. The dried milk left a residual effect the following year for the cover crop of rye. Increased growth on these two plots was pronounced, suggesting two possible factors—the nitrogen in the milk, or the subsequent action of lactic acid which may have influenced the soil flora.

The Absorption by Food Plants of Chemical Elements Important in Human Nutrition. (Walter S. Eisenmenger and Karol J. Kucinski.) Calcium, magnesium, sodium, and potassium salts, at the rate of 200 parts per million of each cation, were added singly to soil growing vegetables. The increase of these cations in plant tissue, when cations were added singly to the soil was as follows: for cabbage—calcium 30 percent, potassium 127 percent, magnesium 543 percent, and sodium, none; for celery—calcium 44 percent, potassium 256 percent, magnesium 390 percent, and sodium 52 percent; for lettuce—calcium 12 percent, potassium 132 percent, magnesium 346 percent, and sodium 72 percent; for carrots —calcium 18 percent, potassium 24 percent, magnesium 42 percent, and sodium 106 percent; and for beet roots—calcium 22 percent, potassium 12 percent, magnesium 85 percent, and sodium 356 percent.

Larger amounts of magnesium, potassium, and sodium can be introduced into plants than of calcium. Also, more of the halides can be introduced into plants than of phosphorus or sulfur.

It may be said that those elements which are abundant in sea water may be introduced into plants more readily than the elements which are abundant in land waters.

The Intake by Plants of Elements Applied to the Soil in Pairs Compared to the Intake of the Same Elements Applied Singly. (Walter S. Eisenmenger and Karol J. Kucinski.) Cabbage, celery, lettuce, and string beans were grown after application to the soil of 250 parts per million each of calcium, sodium, and potassium, singly and also in all possible combinations. Results show that when these ions were applied in pairs, the amounts taken in by the plant were lower than when they were applied singly. This behavior is suggestive of the well-known premise that up to a certain point one of these elements can serve the function or purpose of the other.

Magnesium Requirements of Plants. (Walter S. Eisenmenger and Karol J. Kucinski.) Nearly one hundred species of plants have been grown on a magnesium deficient plot, one-fourth of which receives magnesium sulfate; one fourth.

magnesium sulfate and lime; one-fourth, lime alone; and the other fourth, neither lime nor magnesium.

The demonstrations have developed to a significant degree—to show what plants need this element. However, the obvious chlorosis seems not to be the whole story; for we have found plants regarded as weeds which do not grow at all where no magnesium is added, and one cultivated plant which does not chlorose but does much better if magnesium is added, and there are plants which have symptoms of potassium deficiency where no magnesium is added, as in the case of the apple tree.

Soil Conservation Research Projects. (Karol J. Kucinski and Walter S. Eisenmenger.)

A Study of the Physical and Chemical Properties of Wind-Blown Soils. Wind erosion in the Connecticut Valley occurs mostly on onion and vegetable fields when previously frozen soils thaw, then dry, and are swept off by drying, northwesterly winds. In general, these wind-blown soils are coarser than the soils least affected. It is important from both the practical and academic viewpoints to find out just what physical-chemical properties determine the degree of erodibility of a soil, which of these properties are controllable, and what takes place in the soil complex when one or more of these properties are changed.

During the past year, in cooperation with the Soil Conservation Service, the problem of wind erosion has been studied. Soils from wind-eroded and uneroded areas are being examined by the use of a wind tunnel 32 feet long by 3 feet by 3 feet, especially designed for local conditions. Wind velocities as high as 50 miles an hour can be generated and instruments are used to record the wind velocities and amounts of erosion. Preliminary trials with the tunnel have given interesting results, and it is expected that the information finally obtained will help greatly in understanding why certain soils erode more than others and possibly in establishing means for their stabilization.

A Survey of Erosion Problems Arising from Changes in Land Use. The growing of potatoes on a large scale is a relatively new venture on some of the farms in Massachusetts, especially in the western foothills and plateau. Many acres of old sod have been plowed under on the sloping hillsides—in some cases, fields which have not been in open cultivation for the past thirty years. The potato yields from such fields have been very encouraging and in most cases, therefore, the operators have not been interested in soil conservation practices. As yet, only slight sheet erosion is noticed, probably because of the presence of large amounts of organic matter. Great concern has been felt by some who think that after a few years of open cultivation, the organic matter originally present in these new potato fields will decompose and the soil will readily erode, since cover cropping has not been practiced.

Determinations of carbon and loss on ignition indicate that a large decrease in the organic matter content of some of these soils has already taken place. There was an average decrease of 9.5 percent of soil carbon in 1940 compared with 1939 and a 21 percent decrease in 1942 compared with 1939. The "loss on ignition" of this same soil, which is a measure of organic matter, showed an average decrease of over 10 percent. It is deemed advisable, therefore, to encourage potato growers to practice soil conservation methods such as winter cover cropping and terrace and contour farming of their hillsides.

Sunflowers and their Possibilities. (Karol J. Kucinski and Walter S. Eisenmenger.) For the past four or five years, sunflowers have been grown in the hope of finding out whether the crop is adapted to our soil and climate. Results show that sunflowers can be grown here and produce seed abundantly. However, to

the best of our knowledge, no one in Massachusetts is growing sunflowers in commercial lots, probably because of the lack of proper mills for processing the oil. The cost of transportation to mills in the Midwest would not justify shipment even in normal times. Some seed is grown locally and used as a conditioner of poultry.

Sunflowers will grow in Massachusetts on any land which will produce field corn and a corn fertilizer seems to do very well. There is an element of risk involved in the growing of the crop which should not be overlooked. The plant is very susceptible to damage from windstorms and there was complete crop failure after the 1938 hurricane. The "wind-fall" of the sunflower plant is due to a large extent to infestation with the corn borer. Planting the seed too close will produce small and thin sunflower plants, too weak to withstand strong windstorms. One seed per hill every 18 inches in 36-inch rows gave an average crop of over 2 tons of clean seed per acre. The wholesale price of sunflower seed quoted on the western coast ranges from seven to eight cents a pound.

Sunflowers are hardy to light frost, and can be planted at the time it is safe to plant field corn. Harvesting is usually done during the latter part of September. A growing period of 120 to 140 days, depending on the season, is sufficient for maturing the seed in Massachusetts. It has been found best to cut the sunflower heads off the stalk and place them singly on boards to dry for two or three weeks. This drying facilitates the removal of the seed from the head by striking the head against some object or rubbing it on a very coarse wire screen.

Black Root-Rot of Tobacco. (C. V. Kightlinger.) The project to improve tobacco production in Massachusetts by producing strains of Havana Seed which are satisfactorily resistant to black root-rot and also acceptable in type, quality, yielding capacity, and habits of growth in general, is being continued. Strains of tobacco which possess most of these properties have been produced, but they have not been entirely acceptable to some leaders of the tobacco trade. Attempts to improve the strains by selection have succeeded in making changes but only in minor properties. New strains produced by breeding show promise of producing the desired results.

Results obtained from small plot tests show two of the new strains to yield well not only in soil free from black root-rot, but under bad black root-rot promoting conditions, as well. They have good general type and produce leaves which have good shape, smaller veins than many strains, and good body and quality. These strains mature as early as the common Havana Seed which was used as one of the parents and bear a close resemblance to that parent in most respects. They have not yet been tested in commercial production.

Brown Root-Rot of Tobacco (C. V. Kightlinger.) The project to determine the effects that high and low fertility of the soil may have on the occurrence of brown root-rot of tobacco is in progress, but work has not yet gone beyond the treatment of soil necessary to produce those differences in fertility.

Soil Treatments for Tobacco Seedbeds. (C. V. Kightlinger.) Experiments were made again during the fall of 1941 and the spring of 1942, to test the effectiveness of several different soil treatments in controlling damping-off diseases, but results were disappointing because even the control plots showed no evidence of the disease.

In the control of weeds, there were wide differences between the different treatments; also, between replications of the same treatment, except in the case of steaming and the combination treatments with chloro-picrin and calcium cyanamid. Steaming was done by the pan method at a steam pressure of about 100 pounds applied for 20 minutes, with the pan kept in place for another 20 minutes.

This gave good control of weeds in all replications, whether done in the fall or in the spring. The combination treatment of chloro-picrin and calcium cyanamid consisted of 2 cc. of chloro-picrin per square foot and one-half pound of calcium cyanamid per square yard of soil surface, applied only in the fall. This treatment was not so effective as steaming, but it gave fair control of weeds in most of the replications.

Onion Breeding. (Hrant M. Yegian.) Tests were made during the season of 1942 on the Hubbard farm in Sunderland, Massachusetts, to compare the yields of onions obtained from sets planted by machine with yields of onions obtained from sets planted by hand, and to determine the effect that spacing of sets within the row might have on both the yield and size of bulbs produced.

The sets planted by hand yielded an average of 51 pounds of Number 1 onions per 50-foot row, compared with 33.5 pounds for machine-planted sets with supplementary hand work for checking and respacing. With the machine, the spacing and the yield are not uniform. The number of plants in a 50-foot row varied from 153 to 218, compared with 238 to 264 plants per row in the hand-planted sets. The yield obtained from machine-planted sets varied from 29 to 44 pounds compared with 49 to 54.5 pounds from hand-planted sets. Another important factor affecting the yield and the stand of machine-planted sets is the fact that sets are not always placed in an upright position. There was a loss of 25 percent in yield when sets were placed horizontally in the row by hand, and 80 percent when planted bottoms up in the experimental plot at the College. These figures will, of course, vary from year to year depending on weather conditions prevailing soon after the sets are planted. The weather during April and the early part of May this season was very dry and warm, which may account for the poor start made by sets planted horizontally or bottoms up. Although the machine-planted sets did not yield as well as the hand-planted sets, it would seem that the use of this machine should be encouraged in the Valley because of the saving in labor. Even spacing could be secured by carefully sizing the sets into several grades.

Spacing of sets in the row had a marked influence on the yield and to some extent on the size of the bulbs. When sets were spaced 2.1 inches, 3.2 inches and 4.2 inches apart in the rows, the average yields of Number 1 onions were 51 pounds, 40.5 pounds, and 32.5 pounds per 50-foot row, respectively; and the average weight of bulbs was 0.2 pounds, 0.22 pounds, and 0.23 pounds, respectively.

The data covering one year of field experiments on the effect of storage temperatures on the keeping quality of bulbs and on the subsequent seed-stalk development of mother bulbs at uniform weight (40–45 grams) warrant the following general statement:

1. Bulbs stored at 32°F. kept best. Bulbs stored at 45° had 15 percent of sprouting, while those stored at 60° – 70° had 18 percent of sprouting and 5 percent of soft rot.

2. Bulbs stored at 45°F. were the first to send out seed stalks, followed by those stored at 60° – 70°. The bulbs stored at 32° were 7 – 10 days later than those stored at 45°.

3. The storage temperature had a marked effect on the number of seed stalks produced. When bulbs were stored at 60° – 70°F., 33 percent of the bulbs had 2 seed stalks per bulb; 30 percent, 3 seed stalks; and 25 percent, 4 seed stalks; when stored at 45°, 53 percent of bulbs had 2 seed stalks per bulb; 32 percent, 3 seed stalks; and 8 percent, 4 seed stalks; and when stored at 32°, 76 percent of the bulbs had 2 seed stalks per bulb; 17 percent, 3 seed stalks; and 4 percent, 4 seed stalks.

Although the amount of seed produced by the several lots of bulbs differed, it is not certain that the storage temperatures were entirely responsible for these differences. Further investigation of this phase of the problem is needed.

There was no significant difference in time of maturity between commercially grown onions in the Valley and onions grown from sets selected for early and late maturity. On account of weather conditions this year, commercially grown onions matured from 2 to 3 weeks earlier than usual, which may explain the failure to obtain any advantage from using specially selected sets.

Sets were produced this year from second generation selfed lines for the study of inheritance of number of seed stalks per plant; from crosses for double and single bulb characters; and from crosses between white Persian and Ebenezer variety. F_2 seed was secured from the white Persian × Ebenezer cross.

Sterile-species crosses between *Allium fistulosum* and *A. cepa* L. were treated with calchicine to induce polyploidy. Calchicine in a 2 percent aqueous solution was lethal to all the early stages of inflorescence when immersed for one hour, and few of the flowers that were about ready to open on well-developed inflorescence survived the treatment. Their stigmas were stunted and swollen and no pollen ripened. One of the hybrids which was not treated with calchicine matured 5 seeds. These seeds were planted as soon as mature, in the greenhouse. Although all of the seeds germinated, only two seedlings survived. Cytological examination of the meristematic tissues will be made to determine the chromosome number of these plants.

The hybrids of the *A. fistulosum* × *A. cepa* cross show the characteristics of multiplier onion. One of the year-old bulbs separated into 16 parts, each bulblet having a flower-stalk.

Hybrid Field Corn. (Hrant M. Yegian.) Further trials with early-maturing hybrid field corn for the higher plateau regions of Worcester County and the western counties of Massachusetts were conducted at the College Farm. A few of the promising hybrids will be tested next season in the northern part of the State.

Nine early-maturing hybrids—Maine A, Wis. 240, Wis. 255, Minn. 402, Minn. 700, Minn. 800, Cornell 34-53, Ohio M15, and Quebec flint—from last year's trial plots at the College were tested this year for maturity and yield in the northern part of the State where the growing season is shorter and cooler than it is here. Maine A was the only one that matured under those conditions.

In order to become familiar with the performance of recently developed out-of-state hybrids offered for sale in Massachusetts for late grain and silage purposes, yield tests with 27 hybrids were conducted at the College Farm. The year 1942 was very favorable for corn production. The long ripening season permitted relatively large, late-maturing hybrids to ripen satisfactorily; but in a year with a shorter ripening season, the results may be very disappointing.

Available Phosphorus. (A. B. Beaumont.) The distribution of "available" phosphorus in the soil profile as affected by soil type and management is being studied. Determinations of soluble phosphorus made to date indicate that past treatment is a more important factor in determining the amount of phosphorus extracted by this method than is soil type. Long use of phosphatic fertilizers has caused an accumulation of acid-soluble phosphorus in the topsoil, the amount varying with the degree of fertilization. Topsoils which have been heavily fertilized for years, as in truck growing and tobacco culture, have been found to be relatively heavily charged with phosphorus considered available by the method of extraction used. Corresponding subsoils have been found to contain little available phosphorus.

Potato Variety Trials. (Ralph Donaldson, Walter S. Eisenmenger, and Karol J. Kucinski.) Based on yields of marketable size, the ranking of potato varieties grown in plots at the college during the season of 1942 were Sequoia, Pontiac, Green Mountain, Houma, Red Warba, Russet Rural, Chippewa, Earlaine, S-46592, Katahdin, Sebago, S-46000, and Irish Cobbler.

Ryegrass as a Green Manure Crop. (Hrant M. Yegian.) The use of domestic ryegrass (*Lolium* sp.) as a winter cover crop and green manure is becoming more or less a general practice on the better-managed vegetable farms. It is one of the best all-round winter cover crops in this region, where the temperature during the growing season in the fall is moderately cool. Ryegrass is easily grown, and on fertile soil makes a complete cover quickly. Its heavy mat of roots retards severe soil erosion from wind or rapid run-off of rain. It may be seeded, in most cases, as soon as the previous crop is removed. With set onions, ryegrass may be seeded at the rate of 20–25 pounds per acre, in the early part of August, after the onions have been harvested and moved out of the field, although seeding even as late as the early part of September has given a satisfactory cover crop at this station. The yield (0.5–1.5 tons of dry tops) will vary, depending upon the time of seeding and the amount of available moisture and plant nutrients during the growing period. It is moderately winter-hardy. From 50 to 60 percent of the plants will survive the average winter; so unless the ryegrass is completely turned under in the spring during the plowing operation, volunteer plants may interfere with the cultivation of the subsequent crop. Experience here has shown that a very satisfactory seedbed for the set onion crop can be prepared by plowing under the cover crop in early spring.

Influence of Soil Fertility on Productiveness of Pasture Species. (Hrant M. Yegian.) In 1941 a field plot experiment was started with thirteen species of grass to determine their relative productivity and ability to winter over and to recover from cutting. These grass plots were maintained in pure stand at different levels of soil fertility which were secured by the addition of lime (1000 pounds per acre) and 5-8-7 fertilizer in increments of 400 pounds per acre. Data covering the second year of the experiment warrant the following statement:

All the species continued to respond as well in their second year as in their first, to increases in soil fertility levels.

The soil fertility requirements of different species vary. There was a pronounced or consistent increase in yield with additional applications of commercial fertilizer, but the percentage increase in yield was not the same for all the species at each level of soil fertility. Reed canary grass, colonial bent, orchard grass, and Kentucky bluegrass produced proportionally more dry tops at the higher soil fertility levels (800 to 1600 pounds of 5-8-7 fertilizer per acre); while timothy, fowl bluegrass, red top, and meadow fescue produced proportionally more dry tops at the lower levels (400 to 800 pounds of 5-8-7 fertilizer per acre); and there were a few species, including meadow foxtail and smooth brome grass, that produced in direct proportion to the amount of fertilizer added.

The perennial ryegrass was completely winterkilled in its second year. Kentucky bluegrass, reed canary grass, timothy, and smooth brome grass gave a greater yield in their second year than in the first in the fertilizer plots; meadow fescue, colonial bent, orchard grass, rough-stalked meadow grass, and meadow foxtail produced less in their second year; while red top and fowl bluegrass maintained their yield at the same level both years.

Experiments at Amherst with Hay and Pasture Seeding Mixtures. (W. G. Colby.) Additional data were obtained from three series of plots planted with different hay and pasture seeding mixtures in 1940 and 1941. Details of the

plan of the experiment were given in last year's report (Mass. Agr. Expt. Sta. Bul. 388:14-15, 1942).

Yields of both hay and pasture herbage on plots seeded in 1940 were lower this year than last year. Plots which produced at the rate of 3½ to 4 tons of dry matter per acre last year produced 3 to 3½ tons this year. Reduced yields resulted, notwithstanding the fact that growing conditions so far as the weather was concerned were much more favorable this past season than they were a year ago. Total rainfall for the period from March 1 to November 1, 1942, amounted to 30.55 inches, slightly above normal for this period, whereas the total rainfall for the same period in 1941 was only 22.02 inches.

These experimental results are consistent with what has been observed in newly seeded hay and pasture lands in Massachusetts for many years. Unless weather conditions or other circumstances are extremely unfavorable, yields will be highest the year following seeding. This is true for both spring and summer seedings. Yields can be expected to fall for two to three years following the second year of maximum production until a fairly constant production level is reached, which will approximate one half to two thirds of the maximum figure. Careful grazing management in pastures and regular topdressing applications of suitable fertilizers will slow up the rate of decrease, but they will not prevent it. Managed grazing of the plots in this experiment, together with a topdressing application of 200 pounds of 40 percent superphosphate and 325 pounds of muriate of potash per acre in the fall of 1941, did not prevent yield levels from falling in 1942.

Of the three grasses—smooth brome grass, late-maturing types of orchard grass, and meadow fescue—which produced well in association with Ladino clover in 1941, only meadow fescue failed to compete satisfactorily in 1942. The total production of these grasses in association with Ladino clover was not only high but was fairly uniformly spread over the season. Smooth brome grass and Ladino clover for example, yielded 1015 pounds of dry herbage in May, 1600 pounds in June, 1065 pounds in July, 920 pounds in August, and 770 pounds in October. These yields may be compared with those from the timothy, alsike, red clover plots which were 1210, 1160, 770, 770, and 340 pounds for the same harvesting dates.

Promising results were again obtained from the series in which a crop of hay was cut followed by grazing. A mixture of smooth brome grass, Ladino clover, and alfalfa produced 4040 pounds of hay in mid-June, 1065 pounds of grazing in July, 1015 pounds in August, and 870 pounds in October. The timothy, alsike, red clover mixture yielded 5180 pounds of hay in late June, no grazing in July, 970 pounds in August, and 680 pounds in October.

Some of the leafy, late-maturing strains of orchard grass performed moderately well with Ladino clover and also when alfalfa was added, but the commercial strains of orchard grass were not satisfactory. In the pasture plots they were all too vigorous in their growth habits and tended to crowd out the legumes even though grazing was carefully controlled and the plots were clipped after each grazing period. In the hay plots these strains matured too early for the alfalfa.

Although the common variety of orchard grass has been frequently recommended to farmers, this grass has never found widespread favor. It has recently been recommended as a companion grass for Ladino clover. The past two years' results indicate that the reluctance on the part of farmers to grow it extensively is well founded. Except where soils are fertile and well supplied with moisture and also where grazing is carefully controlled and the means are available for clipping following grazing, disappointing results with Ladino clover and orchard grass are likely. Even under such circumstances no more than three to five pounds of the grass seed should be sown to the acre.

In an effort to eliminate some of the bad features of orchard grass, breeders have developed a number of new and improved strains. Several of these were included in the test and it is from some of these strains that promising results have been obtained. The outstanding one thus far is S37, a strain developed by the Welsh Plant Breeding Station in Aberystwyth, Wales. Three strains from this source were tested — S26, S37, and S143 — but S37 gave the best all-round performance. It is leafy, late-maturing, moderately vigorous and upright in its growth habit, and a reasonably good seed producer. It looked well in combination with both Ladino clover and alfalfa and appeared to be adapted for use as pasture or hay and pasture combined. A satisfactory proportion of legumes to grasses has been maintained for two years in plots seeded with five pounds of S37 orchard grass, two pounds of Ladino clover, and ten pounds of alfalfa.

Svalof's early meadow fescue, a short, narrow-leafed type, grew well the first season with Ladino clover, but was unable to maintain a stand throughout the second season. Commercial strains were eliminated the first season. The Svalof strain has been of interest, because it is apparently immune to leaf rust, a factor which may explain why it is more persistent than commercial strains. Although meadow fescue is apparently unsatisfactory when grown alone with Ladino clover, there are indications that five to eight pounds might be seeded along with four to five pounds of a leafy strain of orchard grass or eight to ten pounds of smooth brome grass, with excellent results. Meadow fescue is a fast-growing grass which establishes itself quickly and would retard weed growth and yield considerable feed while the slow-growing brome grass or orchard grass was becoming established.

Strains of the so-called tall meadow fescue, such as Alta tall fescue, have not performed satisfactorily. They are coarse and unpalatable in comparison with several of the other grasses and offer too much competition for Ladino clover.

DEPARTMENT OF ANIMAL HUSBANDRY

Victor A. Rice in Charge

A Study of the Mineral Elements of Cow's Milk. (J. G. Archibald, C. H. Parsons, and H. G. Lindquist.) For two reasons the work with manganese reported last year was repeated during the winter of 1941-42: (1) the findings were at variance with some earlier work at another station, so it was thought advisable to confirm them; (2) it was desired to investigate the possible effect of metabolized manganese on the development of oxidized flavor in milk.

The results of this second season's work confirmed the finding reported last year that the amount of manganese in milk can be doubled by adding manganese to the ration fed. This additional metabolized manganese did not retard or inhibit the development of oxidized flavor either in ordinary milk or in milk to which copper had been purposely added to accentuate the effect.

The element zinc is being studied this year.

Investigation of the Merits of Legume and Grass Silage for Massachusetts Agriculture. (J. G. Archibald and C. H. Parsons.) War economy has resulted in a definite shortage and a corresponding increase in price of the two most common preservatives for grass silage, molasses and phosphoric acid. Our efforts this year have, therefore, been devoted to a study of other materials which might possibly be used as preservatives, and to an improvement of methods in general so that smaller amounts of preservative or none at all, may suffice.

It was not possible to conduct any feeding trials with the molasses silage stored in the large experimental silo in June 1941. The excellent quality of this silage

was, however, very evident; the odor was mild and sweet, and the cows ate it much more readily than they did a similar lot preserved with phosphoric acid in the same silo the previous year.

A second silo containing 75 tons of mixed grass was inoculated at five different levels at filling time in June 1941, with a pure culture of *Bacillus bulgaricus*. No other preservative was used. This silo was opened in January 1942; there was considerable spoilage at the top and sides and the odor at first was very objectionable, indicating formation of excessive amounts of butyric acid. The odor improved after the top layers were fed off, but continued more sharply acid than the odor of the molasses silage referred to above, although the pH was 4.4 in contrast to 3.9 for the molasses silage. The station bacteriologist was unable to recover *B. bulgaricus* from the silage, which suggests that the inoculation may have played little if any part in the fermentation.

The silage was fed to young cattle; they ate it readily but made somewhat smaller gains than when fed corn silage. This may have been due, however, to inherent feeding value of the original material rather than to method of preservation. It would have been desirable to include another siloful of similar material not inoculated, as a control. This has been done this year, but at this date (Nov. 30) the silos have not been opened.

In addition to the three large silos filled this year, using respectively molasses, bacterial inoculation, and no preservative (control), sixteen miniature silos have been filled, each containing approximately one and a half bushels of chopped grass or alfalfa, and weighted with concrete blocks to produce a pressure of about 120 pounds to the square foot. Two crops, mixed grass and alfalfa, at two different moisture levels, have been ensiled in these miniature silos with the following treatments: (1) no preservative, (2) inoculation with *B. bulgaricus*, (3) salt, (4) *B. bulgaricus* plus salt. At date of writing (Nov. 30) six of these small silos have been opened and their contents studied from a biochemical, and to a lesser extent from a bacteriological standpoint. The outstanding facts thus far are: (1) the excessive amount of butyric acid which has developed regardless of the preservative used, and (2) the complete absence of lactic acid from these silages.

A Study of Urea as a Partial Substitute for Protein in the Rations of Dairy Cows. (J. G. Archibald.) This project has recently been discontinued for the duration of the war. Final conclusions are not being drawn at this time, but results of feeding trials extending over three years indicate that while the urea has been utilized by the cows to some extent it has not proved equal to the standard protein concentrates as a source of nitrogen for milking cows.

The Effect of Feeding Irradiated Dry Yeast on Reproduction and General Health in Dairy Cows. (J. G. Archibald and J. D. Neville.) Two years' results with sixty cows in the Gardner State Hospital herd show no differences of any significance between the cows getting irradiated yeast and those on the control ration. This lack of response may be due to the fact that this herd has always been maintained at a rather high nutritional level. The level of vitamin D fed was approximately 10,000 international units daily per cow.

Determination of the phosphatase level in the blood of twenty of these cows (ten in each group) at regular intervals during January, February, and March of this year showed no significant differences between the groups in this constituent. Since a rise in blood phosphatase is considered to be a sensitive indicator of vitamin D deficiency, it seems evident from these results that the cows in this herd were not suffering from even a slight deficiency of this vitamin; therefore, the lack of response to the feeding of irradiated yeast is quite understandable. The project in its present form and as involving the use of the Gardner herd has been terminated.

DEPARTMENT OF BACTERIOLOGY

Leon A. Bradley in Charge

Nitrification in Soils Containing Plant Residues of Varying Lignin Content. (James E. Fuller, cooperating with the Agronomy Department.) This investigation, so far as the field work is concerned, is obviously seasonal and consequently proceeds slowly. A preliminary statement was made in the 1941 report from this Department (Mass. Agr. Expt. Sta. Bul. 388: 19, 1942). The crops employed were millet, rye, wheat, sudan grass, sorghum, corn, oats, buckwheat, barley, rape, artichoke, tobacco, and sunflower. There were six plots with all of the crops in each, except the sunflower, which was alternated with fallow strips. The crops were grown and then plowed under. The following season tobacco was grown on the plots, and during that season three series of soil samples were collected — one early in the season before the tobacco was planted, another in mid-summer, and the third in the early autumn after the tobacco had been harvested. These samples were tested for their ability to nitrify dried blood and ammonium sulfate.

The general tendency seemed to be that the capacity of the soil to nitrify dried blood declined in mid-summer as compared to the spring, and then recovered to some extent later in the season. There was considerable variation among the different plots, and no definite relationship could be noted between the variety of crop and the nitrifying capacity of the soil of the plot. The ability of the soils to nitrify ammonium sulfate declined markedly, in general, when the early and mid-season samples were compared, and there was little recovery of activity when the late-season samples were analyzed.

The nitrification results are being compared with the production and the grade and crop indices of tobacco grown on the plots. No relationship has been noted, but further study of the data is being made.

The Determination of the Sanitary Quality of Drinking Utensils. (Ralph L. France and James E. Fuller.) This project had been carried on by France, and after he entered the armed service of the country the work was taken over by Fuller, who completed some unfinished work and prepared a report. The results may be summarized as follows: A wet swab with excess moisture squeezed out was more effective than a dry or a moist swab for removing bacteria from used drinking glasses. A diluting fluid containing a phosphate (Butterfield's phosphate) was more effective than distilled water or physiological salt solution for preserving the viability of bacteria on swabs when they had to be held for some time before plates were made. When swabs had to be held for several hours before plates were made, it was found that chilling the containers with ice helped materially in preventing loss of viability of the bacteria. A yeast-dextrose medium similar to that used for the Standard-Methods procedure for plating milk samples gave good recovery of bacteria for swabs. Practical examinations were made of local establishments serving food and drink.

Bacteriological Study of Chocolate Milk. (James E. Fuller and R. W. Swanson, in cooperation with W. S. Mueller of the Department of Dairy Industry.) This study has been completed and the results published. They may be summarized as follows: The addition of chocolate syrups or cocoa powders inhibited the growth of bacteria as compared with growth in the milk without the powders or syrups. Even though the bacterial content of some of the powders and syrups was high, the resultant growth of bacteria in chocolate milk made from these powders or syrups was not nearly as great as was anticipated. Experiments indicated that the tannic substances in the chocolate or cocoa were responsible for the inhibition of bacterial growth.

Bacteriological Studies of Rural Water Supplies. (James E. Fuller.) This project has been started within the year. Some preliminary work along this line has already been reported (James E. Fuller and Sonnia Levine, Mass. Agr. Exp. Sta. Bul. 378, 1941). Present experiments are being done on an amplified scale. The study aims to attempt a differentiation of the intermediate members of the coliform group of bacteria, so frequently encountered in rural water supplies (wells or springs), to learn how many of them indicate serious pollution and how many indicate merely surface wash. The differential reactions (Imvic tests) of these bacteria are being studied at several incubation temperatures, from room temperature to 46°C. (Eijkmann-test temperature), to determine the proportion that are related to the fecal *Escherichia coli*. Present indications are that the use of the Eijkmann-test temperature for incubating the Imvic tests may be useful in evaluating the sanitary quality of rural water supplies.

Laboratory Service. (R. L. France, until July 1942; James E. Fuller, beginning July).

Milk (bacteria counts)	392
Ice cream (bacteria counts)	91
Milk (butter fat)	27
Water	107
Miscellaneous	3

DEPARTMENT OF BOTANY

A. Vincent Osmun in Charge

Diseases of Trees in Massachusetts. (M. A. McKenzie and A. Vincent Osmun.)

The Dutch Elm Disease Problem. The Dutch elm disease caused by the fungus, *Ceratostomella ulmi* (Schwarz) Buisman, and spread by bark beetles was found in Massachusetts in 1941. During 1942, investigation of this disease in the State has had three main objectives: the discovery and eradication of diseased trees; the evaluation of the importance of woodpiles as sources of the causal fungus and carrier beetles; and the elimination of conditions favorable to the spread of the disease.

Results of the inoculation of several species of elm with the causal fungus in early summer under controlled conditions in the greenhouse indicate that all species of elm are susceptible; but American elm (*Ulmus americana* L.) showed symptoms of the disease most promptly and succumbed most rapidly of all species, potted plants of the species being completely killed within 10 days after inoculation. Death presumably is due to a toxin produced by the fungus, but the word "toxin" is here employed only in a nonspecific sense. Studies previously reported by others, as well as the writers' investigations, indicate that microscopic symptoms indistinguishable from those resulting from fungus infection may occur in plants variously treated with sterilized extracts from fungus cultures. If the symptoms are associated with a specific toxin, a neutralizing agent may be found, although no consistently reliable agent has been found by the writers.

Considerable interest in the work has been shown by municipal tree departments and private citizens, and many specimens for laboratory study were received during the past year. Through the cooperation of the United States Bureau of Entomology and Plant Quarantine, valuable information relative to the general distribution of the disease has been obtained regularly. Seven diseased trees have been eradicated in Massachusetts: in 1941, 1 in Alford; in 1942, 3 in Egremont, 1 in Great Barrington, 1 in Westfield, and 1 in Sheffield. The

eradication of diseased trees is under the direction of the State Department of Agriculture which has cooperated also in the entire program. The infection of trees in the southwestern part of Berkshire County and Westfield, Massachusetts, apparently does not indicate direct spread of the disease between these two regions within the State, but rather the introduction of the disease into the State at two separate points, presumably from a common source in the extension of the infestation radiating from the area around New York City.

In order to protect disease-free elms, concerted effort has been directed toward the elimination of freshly cut elm wood. At present this procedure is the most practical control that can be employed effectively in checking the spread of the disease. Since the disease fungus is virtually a prisoner within an affected tree, it cannot spread significantly except as it is carried from a diseased to an uninfected tree by a vector. The best evidence indicates that the smaller European elm bark beetle, *Scolytus multistriatus* Marsh., is the principal carrier insect. This insect invades the bark of weakened trees or freshly cut elm wood, where eggs are laid in galleries engraved between the bark and wood. Upon emergence, the beetles feed on healthy elm twigs and in this manner may facilitate fungus infection of healthy trees if the feeding beetles come from galleries in diseased wood. The beetle is now known to occur in Springfield, West Springfield, and Westfield in Hampden County, and widely in Berkshire County, in addition to the originally known eastern Massachusetts section of infestation which has been enlarged to include most of the area east of Worcester County.

The prompt destruction by burning of all freshly cut elm wood which is well suited for infestation by bark beetles is urged upon all agencies and individuals whose work brings them into contact with it, unless there is complete assurance that the bark will be removed immediately after the wood is cut or other provision is made for the consumption of any fungus-free wood as fuel in cooperative agreements. Tree wardens, foresters, arborists, fire wardens, highway departments, state departments, and public utilities have cooperated generously in aiding in this practical method of protecting disease-free elms. As in the case of all diseases of plants, however, unbroken continuity of the program is most essential.

Other Tree Problems. Sixty-three diseases of thirty-four species of trees, including nine diseases of elm, were identified from approximately 300 specimens and inquiries received during the year. The Cephalosporium wilt of elm was reported from 4 municipalities in which no previous cases of the disease had been reported, making a total of 177 cities and towns in which the disease has been found in Massachusetts. The fungus, *Verticillium* sp., was isolated from several species of woody plants, but no specimens were received from municipalities not included in the total of 96 reported for 1941.

Following an extended period of wet weather early in the growing season, leaf-inhabiting fungi caused considerable damage to foliage. Trees throughout Massachusetts were affected.

A nonparasitic disease of white pine, commonly known as needle-blight, in which needles of the current season discolor to varying degrees beginning near the tips, was rather prevalent both on ornamental trees and in plantations.

At the request of the Massachusetts Tree Wardens' and Foresters' Association, a report on wartime municipal tree programs was prepared, and subsequently a survey of tree diseases and other defects was made, with a view to outlining a program for tree protection and the prevention of damage by defective trees to persons and property. Current miscellaneous activities included the preparation of parts of the program of the annual Five-day Short Course for Tree Wardens, the compilation of a progress report, revision and publication of a manuscript on a Peridermium of northern hard pines, the discussion of the control of wood-

destroying fungi at the Eastern Pest Control Operators' Conference, the preparation of a mimeographed circular on "Trees in War," and the writing of newspaper press releases. Publications referred to are found listed at the end of this bulletin

Damping-off and Growth of Seedlings and Cuttings of Woody Plants as Affected by Soil Treatments and Modification of Environment. (W. L. Doran.) As a result of increasing interest in the beach plum, a native plant heretofore relatively neglected, work is now being done in cooperation with J. S. Bailey of the Department of Pomology on its vegetative propagation, and an article on the subject was recently published. There was no rooting of hardwood stem cuttings, but softwood cuttings rooted fairly well and best (67 percent in 25 days) when taken here in mid-June and treated with indolebutyric acid (50 mg. l., 24 hr.). Work with root cuttings taken in the fall is now in progress.

The vegetative propagation of garden sage, a plant not now available to spice manufacturers from the usual European sources, was investigated in cooperation with A, M. Davis of the Division of Horticulture, and an article published. Untreated cuttings taken in winter rooted well in sand–peat or sandy soil, better than in sand; but their rooting was hastened or improved by treatment for 24 hours with napthaleneacetic acid or indolebutyric acid 25 mg. l

None of the treatments (red cuprous oxide, Barbak D, zinc oxide, Spergon, and Semesan) which were applied to seeds of trees sown in a cold frame in March gave wholly satisfactory protection against infection of seedlings by soil fungi. So far as there were differences in final stands, they were in favor of the use of red cuprous oxide with blue spruce, Barbak D with white pine, and zinc oxide with hemlock, arbor-vitae, Douglas fir, and sycamore.

In propagation by cuttings, it is important to know which species need no treatments with root-inducing substances. It is noteworthy, therefore, that August cuttings of *Actinidia arguta* and February cuttings of *Decaisnea Fargesii*, both of which bear edible fruit, also February cuttings of *Viburnum rhytidophyllum*, rooted 100 percent without treatment.

Cuttings of Norway spruce are not very responsive to treatment with the commonly used root-inducing acids. But the rooting of February cuttings of two varieties, *pygmaea* and *nana*, was hastened and improved by treatments with solutions of manganese sulfate, 1.0 percent and 5 hours for the former, 0.5 percent and 24 hours for the latter. Rooting of late fall or early winter cuttings of Norway spruce, variety *nana*, as well as cuttings of black spruce, yew, and Hinoki cypress was also improved or hastened by treatment with monobasic potassium phosphate 0.5 percent, 20 hours. Rooting of the last named was more improved by this treatment than by indolebutyric acid.

A mixture of sand and European sphagnum peat has been favored as a rooting medium, but an American sedge peat, similarly used, may give better results. January cuttings of *Lonicera syringantha*, treated with indolebutyric acid 50 mg. /l., 24 hr., rooted 92 percent in a mixture (2:1) of sand and Florida sedge peat, decidedly less well in a similar mixture of sand and European sphagnum peat.

To determine the possible effect of a powder-dip treatment in combination with and immediately after solution-immersion treatments, cuttings of Chinese juniper (the variety *torulosa*) taken in February were variously treated. Untreated cuttings rooted only 11 percent. There was 83 percent rooting of cuttings treated with Hormodin No.3 after treatment for 20 hours with indolebutyric acid 50 mg. /l. or naphthaleneacetic acid 25mg. l., while cuttings given only the solution treatments rooted not more than 50 percent.

As compared with our knowledge of soil disinfection prior to seeding, there has been relatively little information available about the disinfection of rooting media for cuttings. When a rooting medium, sand–peat, was disinfected by

steaming, by formaldehyde, or by vinegar within 24 hours before the insertion of winter cuttings, there was injury to arbor-vitae, red cedar, Hinoki cypress, yew, and two species of Ilex. Similar treatment of the rooting medium with steam or formaldehyde four days before the insertion of cuttings was also harmful or of no benefit. Such treatments are apparently more toxic to cuttings, even dormant cuttings, than to some seeds and it is evident that there should be considerable delay between the disinfection of a rooting medium and the planting of cuttings.

Cuttings of white pine, made of the previous year's growth, were taken in late winter. They rooted neither more nor less well in sand-peat previously used for this purpose, or in sand-peat to which soil from under pine trees had been added, than they did in new sand-peat, never before used, or in new sand-peat steam-sterilized fifteen days previously. Fungi in the rooting medium are, it appears from this, without effect on the rooting of cuttings of white pine. Cuttings from different white pine trees differ in rooting capacity, and treatments which improve the rooting of cuttings from some trees are without much or any effect on the rooting of cuttings from others. Rooting of cuttings from some trees was improved by relatively short solution-immersion treatments in relatively concentrated indolebutyric acid or napthaleneacetic acid solutions, by powder-dip treatments with Hormodins No. 2 and No. 3, and by combinations of solution-immersion and powder-dip treatments.

Effect of Chromated Zinc Chloride on Plants. (L. H. Jones.) The scarcity of lumber which is naturally decay-resistant has led to the use of a chemically treated substitute. This has been successful in the case of telephone poles, railroad ties, building supports, etc. However, when such chemically treated lumber was used in the construction of benches in which plants are grown in the greenhouse, results have indicated that the wood preservative may be toxic to the plants, instead of only to the fungi and bacteria which cause decay.

In tests made here, where chromated zinc chloride was used as the preservative, injury to growing plants was very common and was most pronounced during the warmer months and with the more acid soils.

Study of Diseases of Plants Caused by Soil-Infesting Organisms, with Particular Attention to Control Measures. (W. L. Doran.) Seed treatment with a mixture of oxyquinoline sulfate and talc (1:1) markedly improved stands, but seed treatment with a mixture of potassium dichromate and graphite (1:1) gave even better results; as good results, in fact, as did Semesan, Spergon, or red copper oxide with cucumber, cress, beet, tomato, and chicory. Only with pea did Spergon give better results than potassium dichromate. With tobacco, red copper oxide as a seed treatment gave the best results, Spergon the poorest; but none of the seed treatments gave as good results as did formaldehyde treatment of soil.

Sodium nitrite, 1.5 to 3.0 gm. per square foot, applied to soil immediately after seeding, was injurious to crucifers and to pea, not to cucumber, beet, and chard, and it markedly increased the number of plants which lived. Lacking anything better, it could be used as a soil fungicide with some plants, but it did not give so good results as did much lighter applications of potassium dichromate.

Chromates and dichromates of potassium, ammonium, and sodium, applied in solution to soil immediately after seeding, were found to be highly effective soil fungicides, as effective as formaldehyde even in light applications. And, if properly used, they were quite safe as regards effects on germination and growth of seedlings, except with cabbage and other crucifers. Potassium dichromate, 0.4 or 0.45 gm. per square foot (about 43 pounds per acre), was usually enough for protection and great improvement in the stands of seedlings whether the pH value of the soil was 5.6 or 7.1; but the treatment was safer and less likely to retard

growth in the acid than in the slightly alkaline soil. Dichromates usually gave somewhat more complete protection and, if used in unnecessarily heavy applications, retarded growth of seedlings more than did the chromates. But if applied at the time of seeding and at the rate of not more than 0.45 gm. per square foot, the chromates and dichromates of potassium, sodium, and ammonium were without ill effect on cucumber, beet, chard, pea, and bean; and the chromates of potassium and ammonium, especially the latter, gave very good results. Potassium dichromate was most effective and safe when applied to soil immediately after seeding. Applied 24 hours later, it retarded germination of seeds of some species. It gave satisfactory control when applied to soil two weeks before seeding but was less effective when applied more than three weeks before seeding. Chromate and dichromate of potassium, as used, gave more complete protection than did the corresponding salts of sodium. Chromic acid gave superior results only with beet; and the chloride, nitrate, and sulfate of chromium were almost completely ineffective.

Cresol, in as light an application as 1.5 cc. per square foot, immediately after seeding, gave good control, almost as good as did formaldehyde.

A very light application of formaldehyde (4.9 cc. or one teaspoonful per gallon of water) was most effective when applied to soil immediately after seeding, decidedly less effective when applied more than 24 hours after seeding. Growth of beet, cucumber, and lettuce was improved by applications made not more than 8 hours after seeding, but seedlings of pea were injured when the first application was made 24 hours after seeding.

When nutrients in the form of potassium nitrate and precipitated bone or Ammo-Phos were added to a solution of formaldehyde and applied to soil at the time of seeding, the fungicidal action of the formaldehyde was unimpaired. But in a good sandy loam, the growth of seedlings of pepper, eggplant, beet, and cucumber was improved as much by formaldehyde alone as by formaldehyde plus the nutrients.

Starter solutions applied to the soil around tomato plants as they are set in the field cannot, without danger of chemical injury to the plants, carry enough formaldehyde to be effective against soil fungi.

Lacking chemicals, seeds of some kinds, not all, may well be sown on a layer of sphagnum, overlying soil. Damping-off was well controlled in this way, although not so completely as by formaldehyde treatment of soil. Sphagnum so used gave good results with lettuce, cabbage, and cress, the two latter being especially susceptible to injury by formaldehyde; but sphagnum did not give good results as regards either stands or growth of the solanaceous plants, pepper, eggplant, and tobacco.

Chemical Soil Surface Treatments in Hotbeds for Controlling Damping-off of Early Forcing Vegetables. (W. L. Doran, E. F. Guba, and C. J. Gilgut.) This study was completed with the publication of Bulletin 394.

In some additional tests, certain newer chemical materials offered as seed protectants, notably Spergon, Thiosan, yellow cuprous oxide, and tri-basic copper sulfate, showed in many instances value equal to or surpassing Semesan, red cuprous oxide, and zinc oxide on a wide variety of flower and vegetable seeds.

Control of Greenhouse Vegetable Diseases. (E. F. Guba, Waltham.) The various types of tomatoes studied for their reaction to Alternaria early blight were also tested for their susceptibility to Cladosporium leaf mold. Among them seven types were found showing a very slight degree of susceptibility indicated by sparse, yellowish areas without sporulation, molding, or necrosis, and one type showing none of these symptoms and from all appearances immune. In addition,

all six selections of *Lycopersicon peruvianum* (L.) Mill. showed a similar type of immunity. Bulletin 393 embodies the progress and results of several years' work in the development of resistance in tomatoes to Cladosporium. The Bay State variety is showing susceptibility to the new strain of Cladosporium in an increasing number of greenhouses. Nevertheless, many growers have accepted the new variety as a choice forcing tomato. Now that resistance to the new or Bay State strain of Cladosporium has been found, it is being utilized in an effort to combine resistance with desirable commercial type.

Resistance to Tomato Alternaria Early Blight. (E. F. Guba and R. E. Young, Waltham.) Seed of some 37 elementary types of tomatoes offered as possessing significant resistance to *Alternaria solani* (E. & M.) Jones & Grout were secured for trials at Waltham. These tests were purely exploratory, and if suitable resistance appeared, it was the intention to utilize it for breeding purposes in the development of a blight-resistant tomato. Since a large volume of copper fungicides is employed in the control of tomato early blight, this study would appear to represent a worthy contribution to the war effort.

Weather conditions were ideal for the development of early blight, but in spite of repeated artificial inoculations the disease rather consistently became epidemic only in correlation with a heavy load of fruit and maturity of the fruit. Thus many types remained relatively free of the disease until late in the season and then showed it in severe proportions. The largest and heaviest fruited and earliest maturing types consistently showed a high degree of susceptibility, and only nine types showed resistance.

Interrelation of Wettable Sulfur, Lead Arsenate, and Lime in Apple Spraying. (Departments of Botany, Chemistry, Entomology, and Pomology cooperating.) This project is intended to add to our knowledge of insect and disease control and to assist in making improvements in the apple spraying schedule. On this basis special consideration was given to tenacity of sulfur, scab control, spray injury, and insect control.

Disease Resistance and Heredity of Carnations. (E. F. Guba cooperating with H. E. White, Waltham.) Eighteen varieties of carnations were scrutinized for their susceptibility to various important fungus diseases. As was to be expected, in view of the wide host range of *Rhizoctonia solani*, no resistance to this fungus was found.

Twenty-two varieties were studied for their reaction to *Alternaria dianthi* (blight). Virginia, New Deal Ward, Minna Brenner, and Hazel Draper showed a moderate to high degree of susceptibility, but not until long after the benching season. The disease has become increasingly insignificant in recent years.

A high degree of susceptibility to Uromyces rust was shown by Woburn, Olivette, New Deal Ward, Hazel Draper, Paragon, Pink Treasure, Johnson's Crimson, Spectrum Supreme and King Cardinal.

Tests with the branch rot organism, *Fusarium dianthi*, and the root rot organisms, *F. avenaceum* and *F. culmorum*, yielded no results.

Effect of Soil Temperature on Timothy (Phleum pratense L.). (L. H. Jones.) Seedling plants of timothy were transplanted to containers of soil at a high level of fertility. The plants were allowed to establish themselves at a soil temperature of 65° F., after which the apparatus was adjusted to a range of soil temperatures from 50° to 90° at 10-degree intervals. Tiller counts at 50 days showed that soil temperature affected stooling, the number being greater at 70° and tapering off to the extremes of 50° and 90°. At 50° there was a marked tendency for the shoots to be prostrate in habit. This prostrate habit was also noted in a cool greenhouse

with brome grass (*Bromus inermis* Leyss.), meadow fescue (*Festuca elatior* L.), perennial rye grass (*Lolium perenne* L.), and timothy (*Phleum pratense* L.).

The number of tillers was closely associated with the height of the plants, those at 70°F. being the tallest at 50 days. Foliage and stem color were affected by soil temperature. The plants at 50° were a dark green, and those at 60° were intermediate between the dark green at 50° and the light green at 70° and above.

There were enough replications so that half the containers were available for shifting of temperatures, the remaining half being kept at the same temperature as at the start of the test. The shifted temperatures were 20 degrees higher or lower than the original temperatures. By this means it was possible to corroborate the earlier conclusions made at the 50-day period. Plants which had been at 50° F. and were dark green, prostrate in habit, short, and with few tillers, responded soon to the 70° soil temperature by assuming the characteristics of the check at 70°. On the other hand, the plants at 70°, when shifted to 50°, became prostrate in habit, dark green in color, and stopped growing. At temperatures of 80° and 90°, the check plants and those shifted from 60° and 70° were not in a healthy state of activity; but the unhealthy plants shifted from 90° to 70° and from 80° to 60° resumed the healthy appearance of the check plants for these temperatures.

In the final stages, the plants at 90° F. soil temperature were very poor. Several had died and the remainder were stunted and dark green in color. The plants at 50° and 60° had the most and tallest spikes, but the foliage at the base was sparse. The plants at 70° had thick foliage at the base indicating continued vegetative activity. These plants also had the greatest dry weight. It also appears that soil temperatures lower than 70° give greater dry weights than those above 70°. Since careful attention was given to supplying water, the experiment indicates that soil temperature is the governing factor, and not drought, which is frequently associated with long hot spells of weather.

DEPARTMENT OF CHEMISTRY

Walter S. Ritchie in Charge

Chemical Investigations of the Onion. (Emmett Bennett.) The preliminary work on the characterization of the soluble carbohydrates of the Ebenezer onion as reported last year has been extended. The titration of the hydrolyzed sugars with standard iodine and alkali and the determination of the fructose both indicate that the total sugars are approximately two-thirds d-fructose. Syrups of the total hydrolyzed sugars yielded crystals with a specific rotation of $[-41°]^{20}_{D}$, which is of the order expected for a mixture of d-glucose and d-fructose in the ratio of 1 to 2.

By removal of the reducing sugars, a preparation was obtained having a specific rotation of about $[+48°]^{20}_{D}$, and after inversion about $[-17°]^{20}_{D}$. This, together with the large negative enhancement noted on solutions after inversion, is a strong indication that the chief non-reducing sugar is sucrose.

The present work is concerned with metabolic changes which occur in the cell during growth. Samples were taken at intervals during the growing season. At mid-season onions were collected and divided into equal groups, some of which were placed in total darkness for different periods of time. The many forms of nitrogen have been determined as well as the sulfur compounds, organic acids, and carbohydrates.

Some of the chemical changes during normal growth are as follows: Total nitrogen and organic acids decreased as the season progressed; soluble nitrogen and total sugars increased. The increase in total sugars continued until the middle of the season. Up to that time the trend was the same for both reducing and non-reducing sugars; thereafter the main change appeared to be the formation of non-reducing sugars.

The results of the culture work in complete darkness are almost completely opposite those of the control. In darkness the content of solids, total nitrogen, water soluble nitrogen, organic acids, and carbohydrates decreased gradually.

The Hemicelluloses of Forage Plants. (Emmett Bennett.) Previous work at this station has indicated that a considerable difference exists in the content of moisture of forage grasses. An investigation of the polyuronide hemicelluloses of two species, sheep's fescue (*Festuca ovina*) and sweet vernal (*Anthoxanthum odoratum*) which represent grasses of low and high moisture content respectively, indicated that this difference may be due chiefly to this group of substances. The greater content of total hemicelluloses was found in the low-moisture grass, and the nature of these groups in the two species was quite different.

The hemicelluloses of each species, when hydrolyzed, yielded mainly a uronic acid, l-arabinose and d-xylose in the approximate molar ratio of 1:0.2:15.7 in sheep's fescue and 1:2.9:9.3 in sweet vernal. A preliminary examination of the viscosity of the hemicelluloses indicated that those from sweet vernal grass when dispersed in water produced not only the more viscous system, but also the more stable system. Those from the sheep's fescue for the same period and under the same conditions were almost completely flocculated. It would appear, therefore, that the degree of hydration of the two products differs considerably, and that the species containing the more highly hydrated product has the greater original moisture content and contains the larger percentage of l-arabinose.

Lignin and Its Relation to Absorption of Minerals by Plants. (Emmett Bennett.) Special attention has centered around the mobilizing power of isolated lignin as a representative of the residual organic matter in the soil. While it is known that organic matter may absorb free ions in the soil, its role as a mobilizer of ions is not so well established. To determine the possibilities of lignin in this capacity, a container was devised which would hold both the inorganic material (calcite) and the suspension of lignin in contact with each other and allow the suspension to be agitated with a power driven stirrer, to renew the contact, without disturbing the calcite. The lignin was freed from mineral acids by electrodialysis. The extent of mobilization could be noted from time to time by the losses in the weight of calcite. Calculations based upon such a procedure indicated that mobilization did take place over a period of several months in amounts equivalent to a base exchange capacity of about 175 milli-equivalents per 100 grams of lignin. This phenomenon indicates that the residual organic matter as such may mobilize ions from insoluble compounds. A practical application may be in the form of contact depletion.

On the assumption that the high base exchange values of soil organic matter are due to previous oxidations, samples of lignin were oxidized by iodine. Iodoform was obtained as one by-product. The oxidation value amounted to 175 ml. of N/10 iodine per gram of lignin. Base exchange values of the oxidized lignin were about 35 percent higher than those of the control.

Attempts were made to determine the nature of the functional groups most active in base exchange activity by blocking the aromatic hydroxyl group with acetyl groups. This, while not wholly satisfactory, indicated that the hydroxyl groups were chiefly responsible.

Chemical Changes in Cooking Quality of Vegetables. (Monroe E. Freeman.) A quantitative method for measuring the texture of baked potato tissue by estimating the pore space of dried slices was found to be satisfactory. The method was applied to the study of texture changes in tubers during winter storage. Samples stored at 35° and 50° F. for 76 days, 130 days, and 161 days were baked and the texture was measured or estimated by three methods. Center rot and "blackening" appeared in so many tubers that conclusive results were not obtained. From the sound samples available, however, there seemed to be very little change in specific gravity during the storage period. A visual scoring method indicated that the cooking quality, i.e., texture, was lower in tubers stored for longer periods and at the lower temperature. Toluene index of the tubers indicated a small decrease in baking quality with time of storage at the higher temperature, but because the samples were incomplete these results cannot be assessed with any certainity.

Physico-Chemical Properties of Starches. (Monroe E. Freeman.) The anomolous heat capacities of starch–water systems reported in 1941 were carefully studied and applied to dextrin-water systems and to sand and water. The data allowed a clear explanation of the phenomenon and its relation to the bound water in lyophillic colloids and indicated the existence of a general phenomenon of lyophillic systems that hitherto has not been clearly recognized.

The Influence of Base Exchange Capacity and of Exchangeable Ions in Massachusetts Soils on the Availability of Potassium. (Dale H. Sieling.) Pot cultures of synthetic soil for plant growth were prepared by mixing quantities of a typical tobacco soil, the Agawam fine sandy loam, with electrodialyzed bentonite which had been adjusted to fixed calcium levels with calcium hydroxide. These cultures were all of the same reaction and varied considerably in their base exchange capacity. Four levels of base exchange capacity, 7.1, 12.0, 17.0, and 22.0 milli-equivalents per 100 grams, were established. At each base exchange capacity level the soils were fertilized with four different quantities of potassium and with a fixed quantity of both phosphorus and nitrogen. Nitrogen was also added at various times during the growth of the plants. Each culture was prepared in duplicate and contained 7000 grams of synthetic soil. Tobacco, Havana Seed 211, was used to test growth response and nutrient uptake. One plant was grown in each culture and the soils were watered with distilled water whenever the rainfall was inadequate.

Luxuriant growth was obtained in all cultures and there were no apparent nutrient deficiencies or excesses. Growth, as indicated by the dry weight of the plants, was increased very little by addition of gypsum. The cultures having an exchange capacity of 17.0 milli-equivalents gave plants of the highest average weight. There was a tendency for the dry weight of plants to increase as the quantity of potassium increased at each exchange capacity level.

The Fixation of Arsenic in Soils and the Influence of Arsenic Compounds on the Liberation of Fixed Phosphate. (Dale H. Sieling.) Very marked differences in sorption, of phosphate and arsenate were observed when ballmilled Kaolin was used as the sorption substance. When 1-gram samples of ballmilled Kaolin were shaken for two days with increasing quantities of sodium arsenate at pH 3.0 in 10 ml. of solution, there was a linear increase in the arsenate sorption up to about 13.0 milli-equivalents per gram for a solution having 42.5 milli-equivalents. At higher concentrations there was a sharp increase in the amount of arsenate sorbed followed by progressively smaller increases in the pattern of a typical adsorption. When 1-gram samples of Kaolin were shaken for seven days with solutions of the same concentrations, instead of for two days, the sorption

followed an entirely different pattern. As the concentration increased, the sorption followed a smooth curve until 12.3 milli-equivalents per gram were sorbed from a solution containing 40.0 milli-equivalents. As the concentration increased above this point, there was a marked decrease in the sorption of the arsenate and also a considerable increase in the volume of Kaolin (from 1.7 ml. to 5.0 ml. per gram). The amount of arsenate sorbed remained constant at 10.8 milli-equivalents per gram between the concentrations of 40 and 50 milli-equivalents per 10 ml. of solution and then increased rapidly in a true adsorption pattern up to 24.1 milli-equivalents for a solution containing 80 milli-equivalents of arsenate ion. It seems likely that both arsenate and water are sorbed by the Kaolin and at the critical concentration of 40 to 50 milli-equivalents per gram, the water is sorbed more, thus causing the tremendous increase in volume of clay and making it appear as though arsenate were not being adsorbed when one uses the solution concentration as an index of the sorption.

The same type of experiment was made with phosphate solutions and a typical adsorption curve was obtained for this ion. No apparent increase in volume was noticed at any concentration of phosphate and the maximum sorption was found to be about 12.4 milli-equivalents of phosphate per gram of Kaolin. This ion apparently does not have the marked hydrating effect exhibited by the arsenate ion, although it is sorbed in considerable quantity.

The Effect of Orchard Mulches on the Plant Nutrient Elements in the Soil. (Dale H. Sieling and J. K. Shaw.) Three test plots were established in the summer of 1941 to determine whether mulching with hay and glass wool had any effect on the mobilization of the plant nutrient elements of orchard soils. One plot received a two-inch mulch of Fiberglass wool, the second received a liberal application of meadow hay, and the third was surface-cultivated to prevent the growth of weeds. One year after the initiation of the experiment soil samples were obtained from four depths in each of the test plots and analyzed for exchangeable bases and available phosphorus. No material change had taken place in the plant food content of the soils at any depth after one year of the treatments. These results were to be expected since there had been very little decomposition of the hay mulch. More hay has been added to the plots which are to receive hay mulch and samples will be taken for analysis from all of the plots again next year.

CONTROL SERVICES

P. H. Smith in Charge

The fertilizer, feed, seed, and dairy laws are administered as one service and the operations of each of these, with the exception of the dairy law, are completely reported in annual bulletins issued for that purpose.

Besides the regular control activities the laboratory, through its staff, cooperates liberally on numerous research projects active in other departments and also performs many analytical and testing services for State institutions and for private citizens who, because of the nature of their problems, deserve this consideration.

Under the dairy law 5,984 pieces of Babcock glassware were tested and 107 Certificates of Proficiency were issued during the year ending December 1, 1942.

The enlarged emphasis on the vitamin values of all feeds, and commercial feeds in particular, and the increased interest in the manganese content of poultry mashes and in the protein quality of meat and fish products used for feed demands

continual expansion of the analytical service in those fields and, in an attempt to define these values, several special circulars were published during the year in order that the feeder might extend intelligent and deserved consideration to these recently recognized beneficial factors in feed products.

THE CRANBERRY STATION

East Wareham, Massachusetts H. J. Franklin in Charge

The season's cranberry crop was the second largest in the history of the industry, both in Massachusetts and in the United States. There was rather more rot among the berries as they came from the field in this State than has been evident in any other year, and the abnormal decay showed a marked tendency to continue in storage. Fortunately, a lively demand for the berries throughout the selling season, both for commercial canning and as fresh fruit, moved the crop promptly.

Injurious and Beneficial Insects Affecting the Cranberry. (H. J. Franklin.)

Hill Fireworm (*Tlascala finitella* (Walker)). Moths of this species emerged in confinement very late in May and were caged with cranberry branches on May 30. On June 13 many small caterpillars were found to have hatched from eggs that had been laid during the interval. Some of these were as much as a twelfth of an inch long and had done considerable feeding, so they may have been three days old, indicating that the eggs hatch about ten days after they are laid. Some unhatched eggs were found, most of them on the stems of the new cranberry growth. They were oval in outline, much flattened against their support, and about a fortieth of an inch long. The young worms had blackish heads and very faintly striped reddish brown bodies.

The Burrage bog, infested with this insect last year, was examined on June 16. The worms there had channeled some of the cranberry stems toward and to the tips causing them to drop over. Occasional worms, already showing their striping were sewed up in the cranberry tips like black-headed fireworms, but with more frass around them. The infestation on this bog was again quite serious.

Spotted Fireworm (*Cacoecia parallela* (Rob.)). This pest broke out severely on about nine acres of bog in Marion, Mass., early in June. Most of the worms matured by July 8, but some remained till after July 16 when the moths had begun to fly. The infestation was well controlled by dusting with 30 pounds of cryolite to an ac.e on June 25.

Nine species of parasites were reared from this pest, the most prevalent being *Itoplectis conquisitor* (Say), of the order Hymenoptera, family Ichneumonidae; and *Nemorilla floralis* (Fallen), of the order Diptera, family Exoristidae. All the others belonged to the order Hymenoptera, four being Ichneumonidae and three Chalcidoidea.

The spotted fireworms fed on the following weeds on and around the infested bog: chain fern, sensitive fern, marsh shield fern, common brake, flowering fern, saw brier, hardhack, chokeberry, coarse bramble, winterberry, marsh St.-John's-wort, sweet pepperbush, swamp blueberry, sheep laurel, loosestrife, and asters. Loosestrife and marsh St.-John's-wort were evidently favorite food plants of the insect. They were very abundant on the bog and may have largely induced the infestation.

Some pupae of the spotted fireworm squirm vigorously when disturbed, but they are more often inactive. Each of the abdominal segments of the pupa, except those toward the posterior end, has two ridges across the upper surface

with the surface between them very smooth, each ridge bearing a single row of many short, sharp, tooth-like spines pointing obliquely backward.

White Grub (*Phyllophaga*). Young grubs, evidently hatched in June, were found rather abundant in a small area on the station bog on July 13, 1942. They were quite active and all within an inch or two of the soil surface, most of them within an inch of it.

Cranberry Spittle Insect (*Clastoptera*). The young nymphs in their spittle were found as early as June 2. Flooding a bog for 24 hours as soon as an occasional flower had opened wiped out a heavy infestation completely without harm to the vines or crop. This seems to be an excellent treatment.

Cranberry Root Grub (*Amphicoma*). Half of the station bog was treated with seven ounces of sodium cyanide in 100 gallons of water, a gallon to a square foot, late in April and very early in May. The treatment was very successful and did not reduce the crop. It hurt the vines only on a few small areas. Flood water drained from this bog eight days after the application had no poisonous effect.

Army worms (*Leucania*) attacked freely several bogs that had been flooded from mid-May to mid-July to control the root grub.

Grape Anomala (*Anomala lucicola* Fab., formerly reported as *Anomala errans*). Five acres of seriously infested bog, located in the Wenham section of Carver and not heretofore known to be affected by this grub, were treated very successfully with sodium cyanide solution.

Cranberry Tolerance of Certain Materials. Long experience has found cranberry vines very intolerant of sulfur but very tolerant of kerosene and fairly so of copper.

Cryolite, four tons to an acre, was applied to small areas of the station bog on June 20, 1941. Injury from this was very slow in developing but had become severe by July 1942.

A mixture of 4 pounds of calomel and 96 pounds of talc, 100 pounds to an acre, was dusted onto plots of Howes vines on July 1, 1941, with the vines then approaching full bloom. The set of fruit and size of berries were not much affected, the crop turning out to be about as abundant as on the bog around the plots; but the treatment greatly delayed the ripening of the berries and they finally failed to develop a good red color. The berries were picked toward the end of September and were examined chemically and spectroscopically for mercury, but none was found. The vines on these plots were not quite so green in the fall of 1941 as those on the bog around them, and a rather noticeable number of scattered branches died. The treated areas had a normal appearance during the 1942 growing season, but they bore only about a third as much fruit as areas of the same size around them.

Prevalence of Cranberry Insects in 1942.

1. Bumblebees and honeybees were abundant everywhere on Massachusetts bogs during the cranberry flowering.
2. Infestation by Gypsy Moth (*Porthetria*) was light in Plymouth County and moderate on most of the outer Cape.
3. Cranberry fruit worm (*Mineola*) was about normally abundant, more so than in 1941.
4. Black-headed fireworm was normally abundant, more so than in 1941.
5. Firebeetle (*Cryptocephalus*), almost none.
6. Yellow-headed fireworm (*Peronea*) was more troublesome than usual in recent years.

7. Spotted fireworm was generally more abundant than for many years.
8. Lady beetles were unusually prevalent.
9. False armyworm (*Xylena*) was very prevalent, about as in 1941.
10. Blossom worm (*Epiglaea*) was much less than normally abundant.
11. Spanworms were about as usual.
12. Cranberry girdler (*Crambus*) was more harmful than normal.
13. Cranberry weevil (*Anthonomus*) was about as in other recent years.
14. Cranberry spittle insect and tipworm were fully as troublesome as usual.

Control of Cranberry Bog Weeds. (Chester E. Cross.) In all, 155 plots were used during the season to test the value of various herbicides. The more interesting results follow:

Kainit. This potash fertilizer has been advocated as an herbicide for poison ivy and has been used extensively in Europe to destroy charlock and wild mustard in plantings of spring cereals. Results with 56 plots to test its value as a cranberry bog herbicide were not encouraging. No injury to either cranberry vines or weeds followed its use in amounts up to 1000 pounds an acre when the foliage was dry; and enough to burn weeds like poison ivy, loosestrife, beggar-ticks, horsetail, or asters with their foliage wet damaged cranberry vines also.

Zotox is widely advertised as a selective weed killer for eradicating crab grass and various broad-leaved perennials from lawns and fairways. Different amounts of solution of this chemical in various concentrations were tried on 46 plots against some of the more common bog weeds. It proved to be valueless as a bog herbicide, not being effective even on crab grass unless enough was used to injure cranberry vines badly.

Ferrous Sulfate. A solution of this chemical, a pound to a gallon of water, 400 gallons to an acre, was very effective on low cudweed, with little injury to cranberry vines. This weed is often a serious pest on new plantings and on bogs where grubs have caused areas to be bare of vines.

Kerosene. About 20 plots, on a bog flowed for root grubs till July 15, were treated with kerosene between August 2 and 12. A thick mat of crab grass was almost completely destroyed with 200-300 gallons an acre. The same amount killed barnyard grass, spreading witchgrass, and warty panic grass very effectively. Little harm was done to the relatively tender cranberry vines, most of this injury being on plots treated during the middle of the day or when the vines were wet. The time of day the treatments were made did not affect the killing of the weeds.

Ammonium Sulfamate. Results of dry applications of this new chemical on cranberry bogs have been reported heretofore.[1] This year it was tried in solution as a spray and gave some promise of being a useful herbicide for poison ivy, loosestrife, chokeberry, feather and sensitive ferns, and asters, when used at a rate of not more than one pound in eight gallons of water. Stronger solutions, unless applied in small amount and with great care, were usually very harmful to cranberry vines. Not enough work has been done with this chemical to justify conclusions. It is peculiar that, when cranberry vines have been injured by its use, new growth is slow to develop and its leaves are discolo.ed and undersized, this perhaps indicating that the injury is greater than appears. Partly grown cranberries sprayed with ammonium sulfamate solutions reddened noticeably in a few days without showing other definite signs of injury.

[1]Mass. Agr. Expt. Sta. Bul. 378:47, 1941.

Herbarium. A collection of 140 species of the more common bog weeds has been assembled at the Cranberry Station. It will be useful in identifying weeds for cranberry growers.

Blueberries. (H. J. Franklin.) Only 163 quarts of berries were gathered from the station's cultivated patch in 1942. This small crop is explained by the severe freeze that occurred the night of January 10–11 when the temperature at East Wareham fell to 24° F. below zero, probably the lowest at this place in the last 55 years. The interior of all the fruit buds in the blueberry patch became more or less blackened within a day or two. The subsequent fruiting of the different varieties showed that they varied greatly in their tolerance of the cold:

Adams, Cabot, June, Jersey, and Stanley bore no berries.

Katherine, Pioneer, Rubel, and Wareham produced less than half a crop.

Concord bore half to two-thirds of a crop.

Harding and No. 73 (Station culture number) were reduced only moderately from a full crop. This shows clearly the hardiness of the Harding variety and adds to other great values of No. 73 (a Harding-Rubel cross).

Twenty of twenty-six seedlings of a Harding–Rubel cross developed most of their crop, while 44 of the 59 full-grown miscellaneous plants failed to yield any fruit.

It was finally estimated that the crop of the station blueberry patch, as a whole, was reduced 80 percent by the freeze. However, the blueberry bushes were little injured anywhere by this cold, only the fruit buds and tender tips being hurt, thus evidencing the fact that they approach the wild blueberry in winter hardiness.

DEPARTMENT OF DAIRY INDUSTRY

J. H. Frandsen in Charge

Studies on Chocolate-Flavored Milk. (W. S. Mueller.) The popularity of chocolate-flavored milk has grown greatly in recent years. Whether the addition of the chocolate flavoring enhances or decreases the nutritive value of the milk is a question which has been the subject of much investigation but has not yet been completely answered. The following progress in answering this question has been made.

1. *The Effect of Cocoa Upon the Utilization of the Calcium and Phosphorus of Milk.* (W. S. Mueller, with the cooperation of M. R. Cooney of Home Economics Nutrition.) The presence in cocoa of considerable quantities of oxalic acid suggested the possibility of interference with the utilization of the calcium of the milk or the diet, similar to that observed with spinach, beet greens, and other oxalic acid-rich vegetables. It also seemed advisable to determine whether or not cocoa interfered with the absorption of phosphorus, since milk contains a liberal amount of this important element, which is nutritionally closely associated with calcium. The results from an experiment in which 63 albino rats were used showed that the growth of the rats and their utilization of the calcium and phosphorus of milk were affected adversely by cocoa. It would seem, therefore, that the indiscriminate and excessive use of chocolate-flavored foods, especially in a diet low in calcium, should not be recommended.

2. *Effect of Cocoa on the Vitamin C Content of Milk.* (W. S. Mueller.) The addition of cocoa to milk hastened the destruction of vitamin C. This corroborates the results obtained in a preliminary study.

3. *Vitamin K Content of Cocoa and Dairy Products.* (W. S. Mueller.) It has been observed in the study on the availability of the iron of cocoa that the blood clotting time was shortened when the rats were fed cocoa. This observation led to an investigation of the vitamin K content of cocoa and dairy products. Of the various dairy and cocoa products fed, only cultured buttermilk and cocoa shell had any great effect on blood clotting time. These results indicate that the decrease in blood clotting time, which had been observed for rats receiving cocoa, is not directly tied up with vitamin K.

4. *The Tannic Substances of Commercial Cocoa Powders and the Determination of Cacao Purple.* (W. S. Mueller, with the cooperation of J. W. Kuzmeski.) Commercial cocoa powders have been analyzed for cacao purple by Ulrich's method. The average for 6 Dutch processed samples was 8.44 percent and for 9 unprocessed samples, 12.72 percent. The total ash of the ferric chloride precipitate varied from 11.48 to 18.24 percent. The ash of the precipitate consisted mainly of iron and phosphorus, present either as separate oxides or in combination as ferric phosphate. In general, Ulrich's method for the determination of cacao purple in cocoa products apparently leaves much to be desired. However, the results from this study indicate that the ferric chloride precipitate would measure the cacao purple content more nearly accurately if the washing procedure were modified and a correction made for the ash contained.

Improving the Flavor and Keeping Properties of Milk and Some of its Products. (W. S. Mueller.) Further work is being done on evaluating various substances as antioxidants for butterfat. At the outset of this study, the peroxide test was used in conjunction with the organoleptic tests for determining the effectiveness of the various antioxidants. As the work progressed, it became apparent that the peroxide test was not reliable for replacing organoleptic tests. A new chemical test (Chlorophyll Value Test by M. R. Coe, Eastern Regional Research Laboratory, Philadelphia) is being used for butterfat and seems to correspond more closely to organoleptic rancidity than the peroxide test. Today it is more important than ever before that we know how to prevent spoilage of butterfat because the product is being transported and stored under adverse conditions.

A Study of Vanilla Sugars for Flavoring Ice Cream. (W. S. Mueller.) The high price of grain alcohol is discouraging the use of ordinary vanilla extract for flavoring ice cream. Vanilla sugars appear to be a desirable substitute and their advantages and limitations for use in ice cream are being studied. Sixteen samples, including true, imitation, and mixtures of true and imitation, are being analyzed and used to flavor ice cream. In general, the vanilla sugars were found to be of excellent quality and appeared to be suitable for the purpose, and tests with consumers indicated that it was difficult to distinguish between the true vanilla and the imitation product.

An Explanation of the Increased Efficiency of Gelatin in Ice Cream Mix When Initially Aged at 68°F. (W. S. Mueller.) Results obtained in this study indicate that the initial aging temperature of 68°F. produced a more closely knit gel structure, which has many more inter-connected filaments than a structure produced by aging at the low temperature only. The more numerous gel filaments are effective in obstructing the formation of large ice crystals. This appears to be the most plausible explanation for the smoother texture of gelatin in ice cream when initially aged at 68°F. In view of the present national emergency, it seems particularly timely to emphasize the more effective use of gelatin.

Iodoform Taste in Milk. (H. G. Lindquist.) In a study made on off-flavors in milk, iodoform flavor was detected in a few samples. Investigation showed

that it was traceable to treatment of cows for retained afterbirth by the introduction of oil suspension of boric acid and iodoform into the uterus. One cow so treated secreted enough iodoform in her milk one week after treatment to contaminate 200 gallons of mixed pasteurized milk from the herd.

New Stabilizing Materials for Ice Cream. (A. M. Shipley, M. J. Mack, and J. H. Frandsen.) New stabilizers are constantly appearing on the market and arousing considerable interest because of the uncertainty of the supply of some of the commonly used stabilizers. Algatex, Kragel, Kremtex, and laboratory mixtures of monoglyceride and gelatin and of monoglyceride and Dariloid were compared with gelatin (190 Bloom) and Dariloid as controls, for their effect on ice cream mix and on finished ice cream. The results may be summed up briefly as follows:

1. With the exception of Kremtex, all the stabilizers studied were completely soluble at a temperature of 165°F.

2. Dariloid, Dariloid-monoglyceride, and Kragel were basic in reaction; gelatin, gelatin-monoglyceride, Algatex, and Kremtex were acid.

3. After aging 48 hours, the Algatex mix showed the greatest viscosity; the Dariloid-monoglyceride and Kragel mixes were next; and the gelatin, gelatin-monoglyceride, and Kremtex mixes showed the least.

4. None of the stabilizers affected the titratable acidity of the mix to any marked degree.

5. All except Dariloid, which had the least coagulating effect, affected the protein stability of the mix about the same.

6. All the mixes had about the same whipping rate, with no increase from the use of the particular monoglyceride used in these trials.

7. None of the stabilizers affected the flavor of the ice cream adversely.

8. Ice cream containing gelatin, Dariloid, Algatex, and Kragel had a satisfactory body and texture, but Kremtex seemed at times to produce a body that was slightly weak. The monoglyceride tended to make the ice cream firmer and drier and produced a crumbly body.

9. A smooth-melting ice cream was produced by all the stabilizers except Kremtex, which in some instances produced an ice cream that wheyed off slightly upon melting.

10. More than the usual amount of shrinkage occurred during storage when Kremtex and the monoglyceride mixtures were used.

Bulk Versus Packaged Ice Cream. (J. H. Frandsen and A. M. Shipley.) There is as yet no general agreement as to whether ice cream is better marketed in bulk or in packaged form. For reasons of sanitation and convenience, there is a distinct trend towards the marketing of foods in packages, and most of the arguments that apply to other foods are applicable also to ice cream. The results of this study thus far may be summed up as follows:

The amount of shrinkage incurred in the packaging of bulk ice cream is governed to a considerable extent by the serving technique and increases as the overrun of the ice cream increases. A 35 to 40 percent loss in volume results from bulk packaging as compared with packaging direct from the freezer.

Freezer-packaging produces an ice cream very definitely superior in body and texture to that packaged as bulk because it reduces temperature changes, does away with the forced pressure on the ice cream resultant from hand-packaging, and permits the packaging of ice cream in a desirable semi-soft condition. Machine-packaged ice cream can be held at a lower temperature than bulk ice cream and, therefore, keeps in better condition after it is sold to the consumer.

Factors Affecting the Sweetness Perception in Ice Cream. (J. H. Nair III and M. J. Mack.) A study was made of the percentage of butterfat, the source of butterfat, the ratio of fat to serum solids, the pH of the mix, the effects of salts present, the types of vanilla used, and the serving temperature of the ice cream and their effects on the sweetness perception in ice cream. The work has not been completed, but the preliminary study indicates the following conclusions:

There is a relation between sweetness and body and texture of ice cream.

The kind and amount of sugar in high-fat ice cream mixes definitely affect the quality of the ice cream. The use of corn syrup solids seems to prevent a crumbly texture and improves the body.

Temperature definitely affects the sweetness perception; soft ice cream tastes sweeter than hard.

DEPARTMENT OF ECONOMICS

Philip L. Gamble in Charge

Effects of the War and Readjustments in Massachusetts Agriculture. (David Rozman.) This project is devised to take account of agricultural readjustments already in progress, with the expectation of facilitating the attainment of national goals in agricultural production and of providing a basis for a program of individual and public action after the present emergency is over.

So far the investigation has been directed toward obtaining a picture of readjustments in the dairy industry as the most important factor of agricultural production in the State. By analyzing data from the Animal Inspection records it has been possible to determine the distribution of cow herds in relation to their number and size in various sections of the State. Between January 1941 and January 1942, the total number of cows two years old and over on Massachusetts farms declined from 146,424 to 141,302. During 1941 there was a general decline in the number and proportion of smaller herds; while the herds with twenty cows and over increased both in total number and in the proportion of animals in the group. The distribution of cows by size of herds will have a major effect on the agricultural labor problem because, to the extent that production is concentrated in larger herds, there will be greater need for hired labor.

DEPARTMENT OF ENGINEERING

C. I. Gunness in Charge

Cranberry Storage Investigation. (C. I. Gunness, H. J. Franklin, and H. F. Bergman.) The studies on storage of cranberries were continued during the fall of 1942. Samples of Early Blacks from the Experiment Station bog and from a commercial bog were stored in a commercial air-cooled screenhouse and in refrigerated experimental storage at two different temperatures, 45° and 35°. Both lots were picked on September 14, placed in storage immediately, and removed and screened on October 22. The storage and screening loss differed for the two lots of berries, but in both cases was greatest for the air-cooled storage and least for the refrigerated storage at 35°. There was much less difference between the two refrigerated storages than between the air-cooled and the refrigerated.

The berries from the Experiment Station bog were so well colored when picked that no appreciable change in coloring was noticeable in the different storages. Those picked from the other bog were "green" when picked. Those stored at

45° had colored best; those stored at 35°, least; and those kept in common storage were half way between.

Samples of Early Blacks from the Experiment Station bog were stored in a modified atmosphere in sealed sheet-iron cabinets in the refrigerated rooms held at 45° and 35°. This is a repetition of the trials made in 1941 and reported in the 1941 Annual Report. As explained at that time, it was difficult to remove the moisture produced by the respiration of the berries. This year more adequate means were provided for circulating the air from the cabinets through calcium chloride and no such difficulty was experienced. It was found, however, that the temperature inside the steel cabinets remained considerably higher than the temperature within the rooms in which the cabinets were placed. The cabinet in the 35° room had an average temperature of 43° and the one in the 45° room had a temperature of 50°. In comparing storage losses in the modified atmosphere with the losses in air, it was necessary to make allowance for these variations in temperature. While the results are by no means conclusive, they indicate a smaller storage loss in the modified atmosphere. It is obvious that this experiment cannot be carried out satisfactorily until a small sealed room is provided having its own refrigerating coil.

Fruit and Vegetable Drying. (C. I. Gunness in cooperation with Department of Horticultural Manufactures.) A small electric dehydrator was built during the summer of 1942 for use in the Department of Horticultural Manufactures. While planned for experimental work, the drier is of a size and design which makes it suitable for home use.

A variety of vegetables was dried during the summer and trials on the drying of cranberries are now in progress.

Poultry House Investigation. (C. I. Gunness and W. C. Sanctuary.) The housing project for 1941-42 showed an average water content of the litter varying inversely with the amount of insulation all winter from December 1 to March 11. On March 11 the water content of the litter from the non-insulated, partially insulated, and fully insulated pens was 36.6, 26.3 and 25.9 percent, respectively; the average number of birds was 77, 82, and 84; the food consumption from December 1 to February 9 was 24, 22, and 20 pounds per bird; and egg production 45, 42, and 41 eggs per bird. "Blue comb" disease and paralysis reduced production and caused considerable mortality. Each pen started in the fall with 100 Barred Rock pullets.

Horizontal and vertical temperature gradients were taken under electric hovers, some commercial and one home-made. The brooders producing the best results have a rather even temperature gradient from a low point at the outside edge of the hover to a high point in the center of the hover.

One commercial hover had a lower temperature over a rather large portion of the central area. This has been associated with a depression in the litter in the central area under the hover as if made by chicks crowding to keep warm. This particular hover has had high mortality, associated apparently with this crowding, on several occasions during severe cold snaps, sometimes early in the brooding period and sometimes during the latter part of the brooding period.

The study of soil heating cable to dry the litter in a brooder house equipped with an electric brooder was continued during the winter of 1941–42. While the litter can be dried by this means, it was necessary to rake the litter daily to get full value from the heating. Otherwise, the dry litter near the cable becomes a good heat insulator allowing very little drying at the top and permits caking at the surface. The extra work required, together with relatively high cost of current makes the practice impractical.

DEPARTMENT OF ENTOMOLOGY

Charles P. Alexander in Charge

Investigation of Materials which Promise Value in Insect Control. (A. I. Bourne and W. D. Whitcomb.) Work on a cooperative project on investigations of dinitro combinations was concerned primarily with the effectiveness of such combinations against outbreaks of European red mite during the growing season.

A surprisingly heavy infestation of red mite developed in commercial orchards in practically all sections of the State. Evidences of mite abundance and beginning of injury to foliage were noted by mid-June. The attack developed steadily throughout June and reached its peak in most sections by late July and early August. Heavy bronzing of foliage occurred in many orchards, even on varieties which usually were not considered to be particularly susceptible.

Tests with a DN dust (a 1.7 dicyclohexylamine salt of DNOCHP) and a DN spray (a dicyclohexylamine salt of DNOCHP + dispersing and wetting agent, used at the standard recommended strength of $1\frac{1}{4}$ pounds per 100 gallons) were made in nearly all the blocks of the college and station orchard, and in several commercial orchards. Uniformly good control of the mites was furnished by both DN dust and DN spray, and where the applications were made with due care and under suitable spraying conditions no injury resulted.

Special studies of different strengths of the DN spray were made in a block of Baldwin and Wealthy trees. The material was applied at the rate of 12 ounces, 16 ounces, and 24 ounces per 100 gallons. All treatments gave good control of mites on both varieties. Some slight marginal burn was noted in a few cases, but this was so slight and occurred with such irregularity that it could not be definitely attributed to the treatment and was of no commercial significance.

Toxicity tests of the DN dust and of the DN spray upon 15 different types of ornamental trees and shrubs resulted in no measurable injury to the foliage of butternut, elderberry, flowering plum, willow, rose, ornamental crabapple, privet, barberry, Norway maple, red maple, evonymus (several varieties) or magnolia. Sumac, raspberry, and grape showed slight to appreciable injury. Fortunately these would seldom require summer application of insecticides of this type.

At Waltham a commercial DNOCHP material, known as DN-111 and containing approximately 20 percent of the toxicant, was used at the rate of 24 ounces and 12 ounces per 100 gallons of water on Baldwin apple trees infested with European red mite. The spray was applied July 23 when the mites averaged 12 to 16 per leaf. Both dosages gave good control, and no serious injury to foliage was observed although the margin of some of the tender leaves was slightly scorched. As a result of these experiments and others, DN-111 appears to be a very satisfactory material for the control of summer infestations of the European red mite, and excellent control can be expected from sprays containing as little as 12 ounces in 100 gallons.

Control of Cabbage Maggot. (W. D. Whitcomb, Waltham.) The natural field infestation of cabbage maggot at Waltham was heavy and caused commercial injury to 88 to 90 percent of the untreated plants of susceptible varieties such as Golden Acre and Copenhagen Market.

The first eggs were found on May 1 which is about the average date for the last 12 years.

A study of the relative susceptibility of 13 varieties showed 4 early varieties and 3 medium or late varieties with more than half of the plants severely injured or killed and more than 80 percent commercially injured, while 2 early varieties and 4 medium or late varieties had less than half the plants severely injured or

killed and less than 80 percent commercially injured. The most severely injured varieties were Copenhagen Market and Super-curled Savoy; Early Jersey Wakefield showed the least injury.

Tests to determine the possibility of reducing the amounts of corrosive sublimate or calomel in treatments for combating the cabbage maggot during the war emergency showed that two applications of corrosive sublimate at 1 ounce in 15 gallons of water (1-1920) was equal to or more effective than two applications of this material at 1 ounce in 10 gallons of water (1-1280) which is the normally recommended concentration. Calomel-talc dust containing 2 percent calomel was very nearly as effective as the dust containing 4 percent calomel (the normal recommendation) when applied by the mound method; but was significantly inferior to the 4 percent dust when applied twice with a hand duster.

Control of Squash Vine Borer. (W. D. Whitcomb, Waltham.) As in previous experiments, spraying with 1 percent Volck plus nicotine sulfate 1-500 was the most effective treatment.

A rotenone–copper oxychloride sulfate dust containing .75 percent rotenone was also effective and distinctly more satisfactory than a pyrethrum–yellow cuprous oxide dust containing 3 percent of a petroleum solution of pyrethrins.

A DNOCHP–gypsum compound containing 20 percent of the toxicant reduced the borer infestation nearly two thirds but produced only slightly more mature squash than the check. Vines treated with a calcium arsenate–copper oxychloride dust (5.25 percent tricalcium arsenate) were more heavily infested with borers than the untreated vines but produced the largest yield in the experiment, indicating that a light borer infestation, especially after secondary roots have developed, does not seriously reduce the yield of mature squash.

Control of Striped Cucumber Beetle. (W. D. Whitcomb, Waltham.) With the existing light infestation which produced only about one tenth as many beetles as in 1941, a calcium arsenate–copper oxychloride dust (5.25 percent tricalcium arsenate) gave 90 percent protection to cucumbers and complete protection to melons, which is very encouraging in view of restricted use of rotenone during the war emergency. Rotenone–copper oxychloride sulfate dusts containing .75 percent and .5 percent rotenone respectively were about equally effective, the former giving slightly better protection on the cucumbers and the latter on the melons. It is evident that the dust containing .5 percent rotenone will be satisfactory if available. A pyrethrum–yellow cuprous oxide dust containing 3 percent of a petroleum solution of pyrethrins was less effective than the rotenone dusts but generally satisfactory. On the other hand the same pyrethrum dust without yellow cuprous oxide gave only about 50 percent protection, although the yield of melons following the treatment was the greatest in the experiments, apparently because of a partial control of aphids and other sucking insects which spread mosaic.

Control of Onion Thrips. (A. I. Bourne.) In field tests with insecticides the standard combination of nicotine sulfate and soap again proved superior to all other treatments, giving 87 percent reduction of thrips. A commercial rotenone solution proved nearly as effective and gave greater residual protection. A spray composed of castor bean extractive proved ineffective, largely because of its oily nature and poor wetting qualities. A pine oil derivative in a penetrating soap gave 74 percent control. Its effectiveness was not materially increased when derris was added. A commercial pyrethrum dust (Pyrocide) gave 70 percent control, an excellent showing for dust application and good commercial control. Fixed nicotine sprays were only moderately effective, but a nicotine tannate spray gave 74 percent effective control. A nozzle adapted to deliver a solid-cone

type of spray proved much more satisfactory and gave better penetration than the conventional hollow-cone spray.

Ladybeetles and other natural enemies of thrips did not appear in the fields in sufficient numbers to keep step with the rapid increase in thrips during late July, and there was no evidence of the presence of the fungus disease which usually appears in the fields in seasons when thrips are unusually abundant.

The Value of Control Measures to Supplement the Standard Spray Program for Apple Pests in Massachusetts. (A. I. Bourne.) The study of proposed substitutes to replace or supplement present standard materials and practices was shaped to give special attention to replacements for materials subject to curtailment because of the war emergency. This involved a determination of the value of certain non-arsenical compounds and a study of more effective timing of late season applications.

In a study of the effect of pyrethrum on overwintering larvae of the codling moth in their cocoons on the trees, a pyrethrum–kerosene solution was applied to the rough, flaky bark of the main trunk and base of the larger limbs of a small block of apples, early in April while the trees were still in dormant condition. These trees received no other application for codling moth control. Collections of both drops and samples from these trees showed less than one-fourth as many apples with codling moth stings and entrances on the treated trees, as on the checks. The pyrethrum–oil application caused no damage to bark nor retardation of seasonal development. It apparently had no permanent repellent action to codling moth larvae as indicated by approximately the same number of larvae collected in chemically treated bands, from both sprayed and untreated trees, at the end of the growing season.

This treatment eliminates the necessity for most of the scraping of loose bark from the trees and should prove very effective in penetrating the winter cocoons of larvae hibernating in piles of prop poles. These often attract large numbers of larvae and, since they are usually collected in piles at the edge of the orchard, serve as potential centers of infestation often entirely overlooked by the grower.

In orchard tests to determine the value of various non-arsenicals for codling moth control, one application of a fixed nicotine (14 percent nicotine) replacing lead arsenate in the 4th cover spray reduced codling moth damage to 1.5 percent as compared with 4 percent following the present standard schedule. Fruit from unsprayed checks in this block showed 19.4 percent injury by codling moth.

Where fixed nicotine replaced lead arsenate in the 4th cover spray and was also applied in mid-August, samples of fruit at harvest showed less than 6 apples per 1,000 damaged by codling moth.

A modified schedule in which a commercial pyrethrum–rotenone combination was applied in the 2d, 3d, 4th, and mid-August sprays practically eliminated codling moth damage. Lead arsenate was used with this combination but at reduced strength.

An application of fixed nicotine between the 2d and 3d cover sprays to furnish protection between June 12 and July 9 gave increased protection against codling moth, although the effect was not so pronounced as would be the case in a year when codling moth presented a more serious problem.

All of these materials were used with the wettable sulfur for scab control, proved entirely compatible with the fungicides, and held scab to less than 1 percent damage while samples from unsprayed trees showed 92 percent scabby fruit.

Insecticides for the Control of European Corn Borer. (A. I. Bourne.) The warm, dry weather in April stimulated corn borer activity and, as in the previous season, promoted early pupation of the overwintering larvae. Field collections

in the Connecticut Valley showed 20 to 30 percent pupation by the first week of May, and the first moths emerged on May 12. Emergence increased steadily to a peak on June 8 with a gradual reduction during the next 10 days. Coupled with the comparatively small carry-over of borers because of the light infestation in 1941, this early moth emergence, in advance of the development of the corn, resulted in a comparatively light infestation of early market sweet corn although somewhat heavier than in 1941. There was, however, a substantial build-up during the summer and a more normal infestation of the corn which matured in late August and September.

In the experimental plots the insecticidal applications, based on the first appearance of young, newly hatched larvae, were made on June 10, 15, 20, and 25. Precipitation during that period, while it totaled 2.8 inches of rainfall, was so well distributed that there was very little interference with the treatments.

Because of the war emergency and the limited supply of rotenone available, the sale of this material for use on corn was forbidden so that the field tests were confined to a study of the value of nicotine bentonite and dual-fixed nicotine.

Results from spraying with nicotine bentonite (14 percent nicotine) indicated a considerable increase in protection when 3 pounds per 100 gallons were used as compared with 2 pounds, but no advantage when more than 3 pounds were used. Protection was good in all cases. Dual-fixed nicotine dust again furnished good protection.

From the commercial standpoint the contrast between the corn harvested from treated and untreated plots was more pronounced than can be indicated by figures. Many of the ears scored as "infested" in the treated plots contained very small borers which had hatched after the last application but had scarcely penetrated the husks. A large proportion of such ears could be salvaged. Infested ears from the check plots, however, contained many large, fully developed borers; destruction of the kernels was extensive; and most of the ears were worthless.

Potato Spraying Experiments. (A. I. Bourne.) The experimental plots were planted May 4 and 5. The plants made an early start, received no serious set-back to their steady growth during a long growing season, and were for the most part alive and green until killed by frost on September 28 to 29, 146 days from the date of planting.

Flea beetles appeared in large numbers as soon as the plants were up, were very abundant throughout June and early July, and again from late July until mid-August. There were no serious infestations of other insects.

The plots were given 11 applications of spray between June 5 and August 25. In view of the war emergency and the possible shortage of copper for agricultural purposes, special attention was devoted to a study of different strengths of bordeaux, and one plot was given a complete schedule of 2½-2½-50 bordeaux mixture to determine the protection furnished against disease and insect attack by the reduced dosage.

Flea beetle injury was measured by the number of leaf punctures per square inch of leaf area, and varied inversely with the strength of the bordeaux mixture. In every case the addition of calcium arsenate to the bordeaux mixture reduced the number of feeding punctures. The reduction was greatest (one half) in the plots which received the half-strength bordeaux, and was only slight in the plots which received the standard 5-5-50 bordeaux, indicating that the addition of the arsenical was an important factor whenever the strength of lime in the bordeaux was reduced.

Sufficient protection was furnished by all the different strengths of bordeaux to keep the plants alive and vigorous throughout the growing season, and scarcely a trace of blight was noted. In an adjoining plot which was sprayed with a com-

mercial neutral copper fungicide, the plants were badly riddled by flea beetle, began to die down in late July, and a large proportion were dead by late August. The yields in all the bordeaux-treated plots were very satisfactory.

The results in the plots treated with 2½-2½-50 bordeaux were very satisfactory and encourage the hope that, during the present emergency at least, reasonable protection from disease and insect pests may be secured with a considerable saving in materials.

Investigations on the Effect of Insecticides on Honeybees. (A. I. Bourne and F. R. Shaw). The investigations during 1942 were conducted along two main lines:

1. The use of materials that might be added to spray or dust mixtures to repel bees. Of those used, creosote appeared to be the most effective in repelling the bees but injured apple foliage. Tests are being continued to try to find some material that will be effective as a repellent and yet be safe on plant foliage.

2. The effect on bees of materials used as ant poisons, together with an investigation of the danger of bee poisoning resulting from the use of commercial ant baits. The ant poisons tested contained either thallium sulfate or some arsenical, most commonly sodium arsenite. Because the arsenical compounds killed the bees so quickly, there was less danger of the poison being carried back to the hive than in the case of the slower acting thallium compounds.

Experiments with commercial ant traps, used as directed by the manufacturer, indicate that very slight danger to bees will result if the ant poisons are in salve boxes or similar types of containers. The use of sweetened ant baits exposed openly would appear questionable, not only from the danger to bees but also from the aspect of safety to man and other animals.

Naphthalene and Similar Compounds as Greenhouse Fumigants. (W. D. Whitcomb and Wm. Garland, Waltham.) Experimental fumigations using a mixture of monochlor naphthalene 3 parts and flake naphthalene 1 part were continued at various relative humidities. Satisfactory control of the common red spider mite occurred only after ¾ ounce of the fumigant was vaporized in 1,000 cubic feet and the mites had been exposed for 3 hours. Fumigations at 50, 60, 70, and 80 percent relative humidity and 60 F. showed no significant differences as the relative humidity was increased, indicating that this factor is less important than temperature, which has shown increased mortality at the higher temperatures.

Biology and Control of the Apple Leaf Curling Midge. (W. D. Whitcomb, Waltham.) In emergence cages in the insectary no midge flies emerged in 1942 from maggots collected in June and July 1941, while 67 percent of the maggots collected in August transformed to flies in 1942.

Emergence of the first generation flies at Waltham was about two weeks later than in 1941 and oviposition was negligible on the trees under observation. Emergence of flies again occurred July 20–25 and August 8–15, and the greatest oviposition of the season occurred August 18–27. Larvae were collected in bands in large numbers on July 28 and on September 10, and precipitation exceeding 1 inch was recorded at each time. The influence of rain in causing the maggots to leave the rolled leaves was very noticeable.

Treatment of the soil under lightly infested trees with naphthalene flakes at the rate of 2 pounds per 100 square feet gave almost complete control of midge flies for both the first and the second generations. Spraying during the height of the oviposition period of the second generation, caused a measurable reduction in the number of infested tips where a rotenone or a DN spray was used but no reduction where a pyrethrum spray was used.

Control of Common Red Spider Mite on Greenhouse Plants. (W. D. Whitcomb, Wm. Garland, and Wm. E. Tomlinson, Jr., Waltham.) Studies of the pH of the sap of several of the host plants of the common red spider mite showed that the lower the pH of the plant sap the less time was required for the mite to develop from hatching to adult. These results are based on investigations with rose and carnation plants. Preliminary experiments with tomato, bean, sweet pea, snapdragon, gardenia, and chrysanthemum have been made and this phase of the work will be continued.

Among the experimental sprays for the control of the common red spider mite on greenhouse roses, a commercial mixture of gypsum and dicyclohexylamine di-dinitrocyclohexylphenate containing 20 percent of the toxicant, applied two or three times at weekly intervals, gave practically complete control when used at the rate of 24, 20, or 16 ounces per 100 gallons of water with Ultrawet 1-1000 as a wetting agent. On unsprayed plants in the same bench, the number of spiders increased 40 percent during the same interval.

A commercial spray known as technical mannitan laurate reduced the number of live mites 89 percent in four applications at 1-400, and 73 percent at 1-600. Two other rotenone materials gave fair control of the red spider mite and a third material was ineffective.

Several of these materials were more effective against the red spider mite on carnations than on roses.

Control of Plum Curculio in Apples. (W. D. Whitcomb, Waltham.) The effect of different amounts of spray on the control of the plum curculio in apples was studied by applying a measured quantity to apple trees of known size. An application of 1 gallon per 100 square feet was significantly more effective than an application of ¾ gallon, but 1¼ gallons per 100 square feet were not consistently more effective than 1 gallon, indicating that the results might be influenced by factors other than gallonage.

Cryolite, 4 pounds in 100 gallons, used as a substitute for the same amount of lead arsenate, gave somewhat less control of the plum curculio in apples, and caused very severe russet on Delicious apples.

Lead arsenate was used at the rate of 2, 3, and 4 pounds in 100 gallons of spray on Northern Spy for protection against the plum curculio. Results indicated that 4 pounds is necessary for satisfactory control where this insect is abundant.

Biology and Control of the Grape Plume Moth. (W. D. Whitcomb and Wm. E. Tomlinson, Jr., Waltham.) Experimental dormant applications of the commercial DN product Elgetol confirmed previous experiments which showed that a ½ percent dilution did not give satisfactory control under the same conditions where a 1 percent dilution was effective.

The effect of pruning in reducing infestation was studied on two vines. Heavy pruning (removing 79 percent of the nodes and canes) destroyed 72 percent of the eggs as compared with 55 percent destroyed by light pruning (removing 50 percent of the canes and nodes).

New Vegetable Insect Pests. (W. D. Whitcomb, Waltham.) The snout beetle, *Baris scolopacea* Germ., discovered at Arlington in 1941, was quite destructive to Swiss Chard in the vicinity of Waltham. Typical injury consisted of egg cavities and feeding punctures in the stems of the chard, making the stalks unsightly and unfit for market. Preliminary trials with applications of rotenone dust indicated that this treatment will reduce the abundance and destructiveness of this insect.

In the late summer and fall of 1942, several acres of celery, particularly in Arlington, Belmont, Waltham, and Woburn, were severely damaged or destroyed

by the plant bug, *Lygus campestris* L. Typical injury resulted from the punctures by the bugs in the heart and new stalks of the celery. The punctures were usually infected with a bacterial or fungus rot which turned the heart black, making the celery unfit for sale and often useless for any purpose. Reports from growers indicate that spraying with powdered derris and a wetting agent, prepared by the formula recommended for spraying to combat the European corn borer, is helpful and will give satisfactory control if the applications are started while the infestation is light.

The Effects of Solar Heat on the Subcortical Development of Elm Bark Beetles. (W. B. Becker.) In addition to laboratory and field work with *Hylurgopinus rufipes* in Amherst, field work with this species was also carried on in Pittsfield this summer. Work on *Scolytus multistriatus* was carried on in Springfield and Westfield.

Two brief tentative observations on the trend of the field work may be given now. (1) Freshly cut elm logs, not yet infested with the beetles, which were placed (in the early spring) in a north-south position where the sunlight could strike them all day, did not seem to become infested with any elm Scolytids on most of the upper half throughout the season. This applied to logs up to 4 feet 4 inches in diameter with bark up to 2 3/16 inches thick. (2) When Scolytid beetles were already in the bark before the logs were placed in the sun, the mortality due to the high subcortical temperatures generated by the sun's rays varied with the thickness of the bark, mortality being highest and including a broader arc of the upper surface in logs with thin bark. Some factors to be considered in this work are the weather, thickness of bark, and diameter of logs, as well as the effects of heat on different species of bark beetles.

Some New Findings of *Scolytus multistriatus* Marsham in Massachusetts. (W. B. Becker.) This species was found to be abundant at a locality in Springfield and was also found in Pittsfield. Federal scouts attached to the office of the Bureau of Entomology and Plant Quarantine at Bloomfield, New Jersey, uncovered infestations in Williamstown and North Adams.

Insect Pests of Wood and of Shade, Forest, and Ornamental Trees in Massachusetts. (W. B. Becker.) During the year, 249 inquiries were received about such insect pests, involving 72 species. Ants, termites, powder post beetles, aphids, oak twig pruners, Japanese beetles, and secondary tree-boring insects were received most frequently.

DEPARTMENT OF FLORICULTURE

Clark L. Thayer in Charge

Breeding Snapdragons for Varietal Improvement and Disease Resistance. (Harold E. White, Waltham.) Two types of resistance to rust have been observed in snapdragons. The first is inherited as a simple dominant factor which has been reported previously. The second is a modified dominant type obtained from progeny of crosses made with susceptible commercial varieties. The most promising rust-resistant strains are those developed by inter-crossing susceptible commercial greenhouse forcing varieties. These strains are 80 to 100 percent resistant to rust, free flowering in winter, and good seed producers. The plants can be propagated from cuttings and such material has been highly resistant to rust for three seasons in field and greenhouse tests.

Resistance to other diseases, such as Verticillium Wilt and Powdery Mildew, has not been conclusively determined, although in some seasons a few strains have appeared somewhat less susceptible to these diseases than commercial varieties.

Soilless Culture of Carnations. (Harold E. White, Waltham.) The use of gravel as a cultural medium has been continued for demonstration purposes and for comparison of the responses of carnations to various nutrient formulas. Four formulas were used, which gave the following number of blooms per square foot: Ball's, 14.80; New Jersey, 15.77; Ohio 2 WP Modified, 19.33; Ohio 2 WP Modified plus 1½ formula weights of phosphate and potash, 18.61; soil plot (checks), 17.44.

Plants grown in soil and transplanted to gravel require considerable time for adjustment and development of a root system adapted to the gravel medium. The most critical cultural period for the plants is after they are transplanted from soil to gravel. Keeping the gravel too wet soon after planting will cause heavy losses of even the most vigorous plants; and, contrary to what has been claimed, observations show that weak plants give no better results in gravel than in soil.

A commercial grower should not find it difficult to grow carnations in gravel as far as manipulation of the nutrients is concerned; but the costs of installation at present are very high and it is impossible to obtain fertilizer salts or pumps for the duration of the war.

Cultural Requirements of Freesias. (Harold E. White, Waltham.) Freesia corms pre-cured for 2 to 11 weeks prior to planting lost from 3 to 24 percent of their original weight—a greater loss than in the two previous years because of differences in moisture content of the 1941 crop.

Corms planted August 17 to 25 required 173 days to flower; those planted October 20, 133 days; while those planted on November 1 flowered in 123 days. Freesias bloomed earlier when grown in benches than when grown in bulb pans. Increasing the growing temperature to 60 F. in mid-November hastened the blooming of early planted corms by 3 to 4 weeks.

Disease Resistance and Heredity of Carnations. (Harold E. White, Waltham.) Microscopic examinations and germination tests of pollen from 25 varieties of carnations were started in September and continued through October and November. In the early September tests pollen from the four varieties, Johnson's Crimson, Olivette, Barbara Brigham, and Peter Fisher, responded satisfactorily with 60 to 70 percent germination. Subsequent tests made at weekly intervals on pollen from these same varieties yielded very poor results. Freshly collected pollen dried in a temperature of 72°F. for 1 to 3 days and other samples exposed to sunlight for 6 hours failed to germinate. Microscopic examination of pollen did not reveal any morphological peculiarities which could be associated with poor germination responses. A few imperfect or shriveled pollen grains were common to all varieties but were not numerous enough to be considered a factor in causing poor germination.

The size of pollen grains in the different varieties did not vary greatly, ranging from 45 to 49 microns in diameter. A number of giant grains similar to those characteristic of tetraploid plants were found mixed with pollen of normal size. Typical pollen characteristics were spherical shape, external markings of extine being punctate with distinct pores.

Only 5 out of 23 varieties produced seed with self-pollination. Seed production was low, varying from 10 to 21 seeds per capsule. On the basis of observations made on germination and fertilization, it would seem that the ability of pollen to germinate is influenced by environmental conditions present at the time it is formed.

Packet Seed Studies. (Clark L. Thayer.) The Department of Floriculture cooperated with the Seed Laboratory for the seventh season in conducting tests to determine the quality of flower seeds sold in retail seed stores, chain stores, schools, and other outlets. The seeds were tested for germination and performance under field conditions. Results are reported in Control Series Bulletin 115.

DEPARTMENT OF HOME ECONOMICS NUTRITION

Julia O. Holmes in Charge

Vitamin Requirements of Older People. (A. W. Wertz.) The urinary thiamin excretion of three elderly women was followed for a period of 14 weeks. The diet was supplemented with 3 mg. of thiamin chloride for the first half of the period and then with 1 mg. thiamin plus enough yeast to bring the total thiamin to 3 mg. The excretion of thiamin in the urine was almost twice as much in the latter period as in the first period, although the intake of thiamin was identical. This might indicate that there is some factor supplied by the yeast which has a definite effect on thiamin utilization in the body. There was no change in the electrocardiograms from the first period. The hemoglobin values decreased.

The Effect of Temperature on Calcium Metabolism in Growing Rats. (Marie S. Gutowska.) One series of experiments was conducted at temperatures below 57° and above 90°F. (approximately the limits beyond which the albino rat will not breed satisfactorily); and another series at 73° and 83° (corresponding to the normal range of breeding temperatures). In both series the calcium retention was greater in the low-temperature group, whether determined by balance experiments or by carcass analysis. Growth was slower at the low temperatures. Food consumption was considerably larger in the groups of slow-growing rats kept at the lower temperatures, but food utilization was noticeably lower than in the groups kept at the higher temperatures. It was concluded that temperature plays a much greater role in practical nutrition than is now realized.

It is hoped that these findings, if confirmed by tests on adult rats now in progress, may have some bearing on the food requirements of humans as influenced by varying ranges in temperature.

The Effect of Temperature on the Cure of Rickets. (Marie S. Gutowska.) Two groups of six rats each were depleted of their vitamin D and placed in closed cabinets, one group at 66°F., the other at 82°. All received in three days 4 U.S.P. units of vitamin D. Two rats from each group were killed on the fourth, sixth, and eighth day from the beginning of the assay period. It was apparent, both from photographs and from line tests, that the rats kept at the lower temperature showed an earlier response to the treatment and an earlier healing of the rachitic sections than the rats kept at the higher temperature. It was concluded that the biological materials and the temperature at which the bioassay is conducted must be standardized in order to reduce the errors of the test; and that by lowering the temperature, it may be possible to shorten the time of the assay.

Manganese Balance Experiments with Birds. (Marie S. Gutowska with the cooperation of J. W. Kuzmeski of the Feed Control Service.) Manganese metabolism studies were conducted in two series of experiments. The first series was conducted with two groups of laying hens fed for a period of three months on rations varying only in mangenese content (76 p.p.m. and 21 p.p.m.). The droppings were collected every three hours during a period of a week and five periods of a week each formed the series. The second series consisted of the same number

of experiments but was conducted with single hens, not with groups. The rations and the droppings were analyzed and the balance of manganese calculated.

One hen on the low-manganese ration retained approximately one half of the total available manganese daily. This suggests that even 21 p.p.m. manganese in the ration was sufficient not only to keep the hen in a positive manganese balance but also to provide a surplus so that it was not necessary to store all the amount available. The hens fed for some months on the high-manganese ration did not store any manganese, and the daily output was almost exactly the total amount of the daily intake. This means that the hens were in a complete manganese balance and that the whole surplus of manganese added to this ration was voided by the hens.

Manganese and Reproduction of Birds . (Marie S. Gutowska.) Three series of experiments were conducted to observe the effects of different manganese intakes by poultry on reproduction. In the first series, there was no significant difference in the fertility and hatchability of eggs from hens fed at the low (17 p.p.m.) and the high (61 p.p.m.) manganese rations. In the second series, it was found that the hatchability and fertility of the eggs dropped significantly when the birds were fed a ration containing 14 p.p.m. of manganese; but the differences were not significant in the groups fed the rations containing 17 p.p.m. and 61 p.p.m. of manganese, and the hatchability of eggs in these groups was normal.

It was concluded that 14 p.p.m. of manganese in a laying ration is a subminimum quantity which affects reproduction unfavorably; but 17 p.p.m. is probably not far from the threshold value needed, and 61 p.p.m. is ample. Because normal commercial rations usually contain over 40 p.p.m. of manganese, they do not need, in most cases, to be supplemented with this element.

In a third series, there was a highly significant increase in the volume of sperm produced by cocks fed the high-manganese ration as compared with cocks fed the low-manganese ration. The sperm count varied considerably in the two groups of cocks and also in individual cocks on different days. However, no significant difference between the sperm count of the two groups was found. Consequently the increase in the volume of the semen in the group was due not to a change in the density of the sperm but to improved functioning of the testes.

Effect of Dietary Manganese on the Mineral Content of Some Organs of the Hens. (Marie S. Gutowska and Lewis L. Glow, of the Chemistry Department cooperating.) An investigation was conducted to determine whether the manganese content of the diet would influence the mineral contents of the bones, the livers and the kidneys of the hens. One group received a high-manganese ration (61 p.p.m.); the other, a low-manganese ration (17 p.p.m.).

The ability of individual hens to store or retain minerals in their bones, liver, and kidneys varied considerably; therefore large groups of birds are needed in this kind of experiment. The ash content of the bones varied more between individuals of the same group than between the averages of the two groups.

However, the hens on the high-manganese diet had a larger amount of manganese in their bones and in their livers than did the hens of the low-manganese diet; but there was no evidence that manganese could be stored in the kidneys.

The calcium and phosphorus content of the ash of the tibias and sternums of the hens was almost the same for the two groups.

It was concluded that differences in the manganese content of the diet do not influence the calcium and phosphorus content of the bones and the liver but do influence the amount of manganese in these organs. The amounts of manganese found in the bones and livers, after twelve months on a ration lower in manganese than the average commercial ration for laying hens were considered subnormal.

DEPARTMENT OF HORTICULTURAL MANUFACTURES

F. P. Griffiths in Charge

Cranberry Research. (W. B. Esselen, Jr., R. S. Lubitz, C. R. Fellers, and H. J. Brunell.) Cranberry juice was found to have a definite bactericidal action on the oral flora and on pathogenic bacteria frequently associated with gastro-intestinal disturbances in man. This observed action appears to be due primarily to the high acidity of the cranberry.

By means of chemical and microbiological assays, the amounts of several of the vitamins of the "B-complex" present in 100 grams of fresh cranberries were found to be thiamin (vitamin B_1), 4.5 international units; riboflavin (vitamin B_6), 3 micrograms; nicotinic acid (niacin), 33 micrograms; pantothenic acid, 25 micrograms; pyridoxin, 10 micrograms; and biotin, a trace. There was little or no loss of the "B-complex" vitamins in making cranberry sauce and since the cranberries in whole cranberry sauce make up about 40 percent of the total weight of the finished product, the amount of the above vitamins present in the whole sauce was approximately 40 percent of the figures given for fresh cranberries.

Cranberries were found to contain approximately 10 micrograms of vitamin K per 100 grams, by the chick test.

Domestic Refrigeration. (J. E. W. McConnell and C. R. Fellers.) In household refrigerators left-over vegetables kept better and retained more of their vitamin C when stored in covered containers. The most rapid loss of vitamin C occurred during the first day of storage.

Storage of frozen foods for one day in the freezing compartment of the domestic refrigerator was found to be satisfactory. For storage periods of a week, a temperature of 16°F. was necessary to prevent excessive loss of vitamin C. A marked loss of this vitamin occurred at storage temperatures of 20° to 32°.

Either defrosting of frozen foods at a high temperature or slow defrosting at low temperatures resulted in a considerable loss of vitamin C.

The Nutritive Value of Mushrooms. (C. R. Fellers, E. E. Anderson, and A. S. Levine.) Work conducted during the past year shows that fresh and canned mushrooms (*Agaricus campestris*) surpass many of our staple fruits and vegetables in nutritive value. The mineral or ash content of mushrooms is high, particularly in iron. Mushrooms have been found to be one of the best plant sources of thiamin, riboflavin, pantothenic acid, and nicotinic acid. They also contain significant amounts of ascorbic acid and vitamin K.

Red Squill Research. (A. S. Levine, C. R. Fellers, and L. R. Parkinson.) Work on the toxicity of red squill (a raticide) was continued, and a standardized assay method has been developed.

Preservative Values of Organic Acids. (A. S. Levine, M. G. O'Connor, and C. R. Fellers.) The bactericidal value of benzoic acid is somewhat greater than that of several of its salts. Magnesium and ammonium benzoate compared favorably with sodium benzoate in inhibitory properties. Calcium benzoate was the least toxic of the several compounds tested. It is assumed that the undissociated benzoic acid molecule is the active germicidal agent that represses yeast growth.

Sodium chloride and ethyl alcohol in apple juices which were treated with sodium benzoate markedly inhibited the growth of yeasts. The presence of 30 percent dextrose in apple juice caused some inhibition of yeast growth, its inhibitory power being greater than that of sucrose under these conditions.

Glass Container Research. (W. B. Esselen, Jr., E. L. Moore, J. J. Powers, and C. R. Fellers.) As previously reported it has been found that ascorbic acids function effectively as antioxidants for glass-packed foods. Only that amount of ascorbic acid needed to react with oxygen present within the sealed container is beneficial as far as color and flavor changes are concerned.

The results to date indicate that the addition of ascorbic acid to fruits and vegetables naturally low in vitamin C protected them from discoloration and flavor changes. Ascorbic acid functioned successfully as an antioxidant for peaches, pears, plums, and carrots; was only moderately successful with applesauce and beets; and had no effect on such products as snap beans and peas, known to be moderate to good sources of vitamin C.

It was found that oxygen and the decomposition of ascorbic acid are the principal factors involved in the darkening of packaged orange juice. The darkening is accelerated by warm storage temperatures, but rate and intensity of darkening were significantly affected by exposure to intense light.

Deleterious flavor changes in canned and bottled orange juice occur very soon after the juice is packed, and are associated with the methods used in the preparation of the juice rather than with the type of container or the vitamin C content of the juice.

Tests conducted with glass-packed fruits and vergetables stored at room temperature for one year showed that, under average commercial conditions, there is no danger that light will cause the color to fade.

The Antioxidant Properties of D-Iso Ascorbic Acid. (F. J. Yourga, W. B. Esselen, Jr., and C. R. Fellers.) Preliminary feeding tests indicate that d-iso ascorbic acid has an antiscorbutic potency about 1/25 that of l-ascorbic acid (vitamin C).

Evidence has been obtained which indicates that d-iso ascorbic acid may be used as an antioxidant to prevent or retard the oxidation of l-ascorbic acid in packaged foods.

Fruit Jellies and Jams. (A. S. Levine, S. G. Davis, W. H. Fitzpatrick, and C. R. Fellers.) The beach plum (*Prunus maritima*) is characterized by a distinctive astringent flavor. It is relatively high in ash and carbohydrates and slightly low in pectin as compared with some other varieties of plums. A number of highly desirable products can be made from this fruit, among which jam, jelly, and butter are the most popular. Generally the fruit is deficient in pectin for jelly purposes, and addition of pectin was found necessary for the production of a high-grade jelly. No added pectin was necessary for the jam or butter.

The substitution of pectin and corn sugar for cane sugar has been found feasible in jelly making. While the jelly is of fair quality, it is somewhat higher in cost and lacking in flavor when compared with jelly made with all cane sugar.

Apple Products. (A. S. Levine, F. P. Griffiths, S. G. Davis, C. R. Fellers, J. J. Powers, and W. B. Esselen, Jr.) A cider apple jelly of highly desirable taste, flavor, and color was prepared by adding sweet Baldwin cider, concentrated to one-third its original volume, to the heat-extracted apple juice from an equivalent weight of apples. The amount of dry sugar added was about 60 percent of the apple stock used. The remainder of the sugar was naturally present in the added cider. The mixture of concentrated cider, extracted apple juice, and sugar was concentrated by boiling to a soluble solids content of 68 percent by the usual jelly manufacture procedure. Cider apple jelly is a distinctive product of attractive color and appealing flavor, superior in quality to either apple jelly or cider jelly alone.

Work has been done on the farm and home production of apple syrup to replace sugar and corn syrups. Partial neutralization of the acid in fresh apple cider with baking soda and concentration of the cider approximately seven to one produces a sweet, pleasant-tasting syrup which can be used on the table or for making apple sauce, apple butter, mince meat, or other products. As most fresh apple ciders contain between 10 and 13 percent of sugar it only requires between six and seven quarts of cider to produce one quart of syrup. Clarification of the syrup can be obtained by proper use of gelatine but for most home uses it is not considered necesssary. Many New England farms having cull apples, a cider press, and a maple sugar evaporator are in a position to make large quantities of this syrup.

Marine Products Research. (C. R. Fellers and R. G. Tischer.) A successful method for canning the blue crab (*Callinectus sapidus*) which is common along the Central and Southern East Coast of this country has been developed in this laboratory. A preliminary investigation has been made to find out whether this method is equally satisfactory for the canning of the sand crab (*Platyonichus ocellatus* Latreille), an edible crustacean which abounds in coastal waters from New York to Nova Scotia. The aluminum dip method for preventing discoloration of canned crab meat was found to provide a satisfactory procedure for the packing of sand crab meat in both glass and metal containers.

The Effect of Processing on the Available Iron in Foods. (F. R. Theriault and C. R. Fellers.) The dipyridyl method for available iron gave consistent results for fruits, vegetables, and fish and checked with the bioassay method.

The commercial quick freezing of foods was found to increase the availability of iron slightly. Canning in glass had little or no effect on total and available iron.

Foods canned in tin showed changes in iron content somewhat correlated with their hydrogen ion concentrations. No change or slight gains in iron content were observed with vegetables, and considerable gains in iron occurred in the case of the more acid fruits. Fish (red perch), with a pH value of 6.9, lost half of its total iron and nearly all of its available iron when packed in tin cans lined with zinc enamel (C-enamel). With semi-acid and acid foods the iron gained from the can was nearly 100 percent available.

The Development and Control of Molds in Vanilla Beans. (F. W. Wenzel, Jr., A. S. Levine, and C. R. Fellers.) Vanilla beans which have been properly cured and aged are resistant to molds because of the presence in the beans of natural compounds, such as vanillin, which possess mycostatic properties. Improperly cured beans are susceptible to the growth of the saprophytic *Aspergilli* and *Penicillia*. Moisture and humidity regulation, refrigeration, and storage of the beans in carbon dioxide may be utilized as means of partial mold control. Ultraviolet irradiation of the beans is of little value as a control measure. Prevention of mold growth may be secured by immersion of the beans in an alcoholic vanillin solution or by vacuum fumigation with ethylene oxide.

The Use of Levulinic Acid as a Food Acidulent. (C. R. Fellers, R. G. Tischer, and B. J. Doyle.) The present shortage of the acids commonly used in foods has created a need for adequate substitutes. Levulinic acid (B-acetylpropionic acid) may now be prepared from corn at a fairly low price. Laboratory and clinical tests have shown that levulinic acid, even in excess of amounts that might be commonly used, is non-toxic to humans, rats, guinea pigs, and chickens, and suggest that levulinic acid in small amounts may be safely used to acidulate foods or beverages.

Jellies and carbonated beverages were successfully prepared using levulinic acid. Tests in bread and other bakery products indicate that levulinic acid is at best only weakly mycostatic.

Dextrose Investigations. (W. B. Esselen, Jr., H. Fram, and A. S. Levine.) It was found that sucrose and dextrose had similar effects on the thermal resistance of microorganisms commonly associated with the spoilage of acid food products.

DEPARTMENT OF HORTICULTURE

R. A. Van Meter in Charge

Nurseryculture. (C. J. Gilgut.) In the commercial culture of ornamental plants interest has been confined almost entirely to the production of esthetic effects. During the early stages in the development of a research program with plants in this class, it was necessary to devote much attention to the study of their habits to learn their response to cultural practices. While the results may not have contributed anything sufficiently conclusive to justify recommendations for use in comn ercial production, they have unquestionably prepared the way for the development of a sound research program which is gradually being formulated.

DEPARTMENT OF OLERICULTURE

G. B. Snyder in Charge

Variety Studies. (W. H. Lachman and G. B. Snyder.) The 1942 season was very favorable to the growing of vegetables and furnished excellent opportunity for testing some of the newer strains. Tomatoes, cucumbers, sweet corn, Pascal celery, and beans were given special consideration. While nothing significantly conclusive resulted from these tests, information has been gained concerning habits and cultural response that will serve in evaluating the merits of the several varieties and strains included in this study.

Asparagus Investigations. (Robert E. Young, Waltham.) In the asparagus breeding plots, yields from selected strains were 60 percent higher than last year. The increase in production was quite uniform for all strains, even though the best produced just twice as much asparagus per plant as the poorest. This poorest strain was commercial Mary Washington, indicating that with the proper selection of parent material the yield can be greatly increased. The order of yield of these strains has followed fairly closely the average yield of the parent plants.

Although the yield was so much higher, the average size of spear showed only slight increase, and this did not seem to be correlated with yield or size of spear in previous years.

A division of the spears, during harvest, into four different sizes showed that the percentage of both small and large spears has remained quite constant for all strains for all years and that the change has been a decrease in the medium size and an increase in the very large. The percentage of very large spears varied from 53 percent for the highest yielding strain to 25 percent for the lowest yielding; so the best strain from the standpoint of yield was the best from the standpoint of quality also.

Rust varies with seasonal conditions, but some selected strains showed only 52 percent infection as compared with 83 percent for the commercial strain. Rust of sufficient severity to cause any injury to the plant occurred on only a fourth of the total population. This compared with 14 percent on the old asparagus plants growing alongside, from which the strains under comparison were derived; and 67 percent for a row of the Paradise variety, known to be more susceptible to rust.

Vegetable Breeding for Improvement of Quality. (Robert E. Young, Waltham.) During the year breeding and general varietal studies were conducted with a number of the common vegetables including tomato, Summer Pascal celery, lettuce, rutabaga, beet, greenhouse cucumber, broccoli, and carrot. While there has been an extensive accumulation of information concerning the possibilities and habits of these several vegetables, the results are not sufficiently conclusive to justify detailed discussion, except in a few cases.

Trellis Tomato. The breeding program to improve the internal quality of the two strains of trellis tomatoes developed here was continued with a very satisfactory crop. Since most of the tomatoes that have better internal quality are later maturing, some of the desirable F_2 population has been back-crossed to Trellis No. 22 to get earlier yield. A small early tomato, Denmark, has also been used for some of the back crosses. Some new hybrids were made in the greenhouse and planted for the summer crop, to determine what varieties could be combined with Trellis No. 22 to take advantage of the hybrid vigor.

The most productive hybrid tried this year was Trellis No. 22 × Maine No. 85. This produced an early yield 44 percent greater than Trellis No. 22, with an 11 percent greater total yield, although the percentage of No. 1 fruits was only slightly larger for the hybrid. Work with this hybrid will be continued. There were other first-generation hybrids that produced an increase in yield, and the second generation hybrids were above average in early yield.

Greenhouse Tomatoes. The spring crop of tomatoes was used as a test crop in the use of a hormone spray to produce fruit without seed. Every other plant was treated by spraying the cluster about the time two to three blossoms had opened. Three applications were made one week apart, and some of the buds on the second cluster were small at the time of the last spray. The use of the hormone spray almost doubled the average set of fruit on the first cluster. The spray did not make so much difference in the set of the second cluster — 52 percent for the sprayed, compared with 39 percent for the unsprayed. For both clusters, the three sprays produced a set of 64 percent compared with 38 percent for the untreated plants. There was no noticeable difference in flavor between the seedless fruit and that having seed.

The disadvantage of this spray is that it must be confined to the flower cluster because it affects the foliage about the same as severe mosaic. The labor of putting on the spray, where it has to be applied several times, is considerable; and further trials are necessary before its practical value can be determined.

Rutabaga or Cape Turnip. As reported last year, three distinct types of Rutabaga have been developed and were ready for trial, and six lots of these three types were distributed in Bristol and Barnstable counties.

No. 1 has typical Cape turnip foliage and root shape. The chief distinguishing feature is the absence of green coloring matter in the exposed shoulder, which, however, develops a purple color when exposed to the sun. When grown with sufficient foliage to furnish shade, the shoulder as well as the bottom of the root is white.

No. 2 is a uniform type having white flesh and a green shoulder, and in general resembles the White Cape strains.

No. 3 has yellow flesh and green shoulder and is, in its general characteristics, like the White Cape. Its smooth green shoulder is quite different from that of the usual yellow type.

Careful observation and study led to the conclusion that Nos. 1 and 3 were deserving of consideration for general distribution in the turnip-growing sections of the State.

Hutchinson Carrot. A crop of seed of the hybrid carrots which have been under development was produced in the greenhouse. This hybrid strain, compared with the regular Hutchinson in the fall crop, showed better interior and exterior color with good length and shape. On account of slower growth, however, it is not so well adapted for the early market, and attempts to improve it by breeding and selection are being continued.

DEPARTMENT OF POMOLOGY

R. A. Van Meter in Charge

The Influence of Various Clonal Rootstocks on Apple Varieties. (J. K. Shaw and L. Southwick.) The stock bed set in the spring of 1940 yielded in the spring of 1942 at the rate of from about 6000 to over 20,000 rooted layers per acre. The 18 clonal types may be classified as follows:

Low yields: II, IX, X, XII, XV, A, C, Spy 227.
Medium yields: I, III, VII, VIII, F.
High yields: IV, V, XIII, XVI, Vt. 323.

This classification represents, in general, about what may be expected from these stocks, but owing to the small areas involved, there may be some that are wrongly classified. Probably Malling VIII will usually fall in the low yielding class and II in the medium class.

Many of the individual plants have died following this cutting in the second year. The number of these failures seems to differ with the different stocks. Perhaps a stock bed should be allowed to grow at least two years before severe cutting, so that larger, more vigorous root systems may be established.

The trees in our own six-year-old clonal stock orchard continue to grow vigorously and some trees have borne fair crops for their size. Thus far, there are no significant differences in the increase in trunk diameter due to stock influence. This is probably not true in all the cooperative orchards, for soil and other environmental influences are important factors in the interrelation of stock and scion.

Lethal Incompatibilities between Clonal Stocks and Varieties of Apples. (J. K. Shaw and L. Southwick.) The clonal stock Spy 227 was budded in 1941 to Stayman, Winesap, and two strains of McIntosh. In 1942 nearly all buds started to grow, but Stayman failed to develop and by midsummer most of the trees were dead or dying. Winesap failed a little later. One of the McIntosh strains grew normally all summer and the trees are now good one-year trees, while the other strain behaved like Stayman. Several strains of McIntosh and several varieties belonging to the "Winesap group" were budded on this stock in 1942 to see whether these varieties will act in the same way and how extensive this type of relation may be.

There seem to be lethal combinations between certain flowering crabs and certain Malling stocks. Bechtel crab failed to grow on Malling III. These combinations are being studied further.

Tree Characters of Fruit Varieties. (J. K. Shaw, A. P. French, O. C. Roberts, and L. Southwick.) The usual examination of commercial nurseries for trueness to name was made in the summer of 1942. While occasional new mixtures were found in inspected nurseries, the number of misnamed trees was small compared with earlier years. As the work was extended mixtures were found in cherries, pears, and plums. Increased attention is being given to peaches and thousands of misnamed peach varieties are being eliminated although it is not possible to give this as complete a service as other tree fruits. The only way to be sure that peach varieties are invariably true to name is by the maintenance of a scion orchard, known to be correctly named, as a source of renewal of budding stock.

Comparison of Cultivation and Sod in a Bearing Orchard. (J. K. Shaw.) Of the cultivated plots, one is now under the mulching system and is reported under the following project. Another which had no fertilizer from 1921 to 1927, but has since received nitrate of soda at the rate of 300 pounds per acre, has developed symptoms of both potash and magnesium deficiency. If potash is applied to correct this deficiency a magnesium deficiency will appear on soils not well supplied with this element. Where nitrate of soda alone is used over a period of years a potash deficiency appears on our soils under cultivation after about 10 to 15 years.

One of the sod plots of 10 trees which had been fertilized with nitrogen alone has received a N-P-K fertilizer and another similar plot a N-K fertilizer for the past four years. These plots now show a difference in yield, with the N-K plot yielding best. Both plots have increased yields over the period when nitrogen alone was applied thus dispelling, at least to this extent, the general contention that only nitrogen was necessary as an orchard fertilizer.

Comparison of Cultivation and Heavy Mulching of Apples. (J. K. Shaw.) The plot of nine Wealthy trees which had been mulched for 20 years continues to show superiority over the similar adjoining plot which has been under cultivation and cover crop, although no additional mulch has been applied for the past four years. There is still a thick layer of decaying mulch through which grasses, mostly quack grass, grow luxuriantly. General observations suggest that when a young orchard is planted immediately following the removal of old trees, much attention should be given to building up the soil which has been exhausted of organic matter and nutrients, because it is conceivable that old trees may be able to maintain themselves quite well on a soil so deficient that newly planted trees are unable to establish themselves and special fertilization should be provided.

The two plots in the 14-year-old McIntosh clonal stock orchard near by were mulched as last year and the yield was significantly greater than that of adjacent trees in a Ladino clover sod. No fertilizer has been applied since mulching began; while the trees in the clover have received moderate applications of nitrogen and potash. The foliage on the mulched plots was of a deeper green color and persisted longer in the fall than on the adjacent trees. No signs of a nitrogen depression have appeared on these mulched plots following the application of liberal amounts of higher carbohydrate material.

The Effect of Orchard Mulches on the Plant Nutrients in the Soil. (J. K. Shaw in cooperation with the Chemistry Department.) This project was continued by a second application of hay mulch under the mulched trees and collecting soil samples for analysis as last year. Grass growing up through the mulch of glass wool was suppressed. No differences in the behavior of the trees was observed. The objective is the study of the behavior of nutrients in the soil. Further comments may be found among the Chemistry projects.

Studies of Varieties of Fruits. (J. K. Shaw and Staff.)

Apples. Anoka has fruited for several years. It is not equal to Duchess for commercial purposes, and its only value for us is its tendency to fruit very early in its life.

Close is an early apple, first sent out as U.S.D.A. 57. It is fairly promising as a red early apple of Yellow Transparent season, but variable in size and shape.

Webster is a large red apple originated at the New York Experiment Station. It is attractive in size, shape, and color and begins to bear early but is suitable for cooking only.

Van Buren is reported to be a bud sport of Duchess. It is remarkable in that nursery trees can be distinguished from Duchess. We know of no other bud sport in propagation that can be so distinguished from the parent variety. It is promising to replace Duchess if one wants better color.

Pears. Two Bartlett-like pears, Berger and Conference, have come into bearing. Berger seems to be the more promising, but it remains to be seen whether it can compete with the well-established Bartlett. Conference seemed not equal to Bartlett.

Peaches. N. J. 105. Large, yellow-fleshed, attractive, freestone, flesh fine to firm, should be good shipper, quality good but not outstanding, will bear watching. Ripe August 20.

N. J. 102. Large, attractive, yellow-fleshed, freestone, excellent quality, fine-textured firm flesh, ripens a few days ahead of N. J. 105. Looks very promising.

Red Rose. Flavor tart and slightly astringent even when ripe, disappointing.

Blueberries. GN-87. A small crop was produced on a budded bush. The berries were very large, firm, short-stemmed, oblate, very good blue, very attractive, and very good flavor. The clusters were large and compact making picking a little hard. Skins tore some during picking. Season late medium to late. Had some mummy berry. Looks very promising.

Scammell. This variety performed much better than ever before. It yielded more and larger berries, and berry size held up better during the season. Nevertheless, the yield is still too light for it to compete with commercially recommended varieties.

Raspberries. Tahoma is a bright red berry, not firm and of poor quality. So far it does not seem promising for Massachusetts.

Washington is a large, firm berry of good quality. Worthy of further testing.

Mercy continues to promise well. It seems superior to Taylor, and may prove worthy of cultivation here.

Nature of Winter Hardiness in the Raspberry. (R. A. Van Meter and A. P. French.) A plantation of 22 raspberry varieties was set in the spring of 1942, including the hardiest varieties and those most susceptible to injury by cold. Preliminary trials of canes from older plantations suggest that the buds of varieties most often injured by low temperatures have very short rest periods.

Storage of Apples in Modified Atmospheres. (L. Southwick and O. C. Roberts, in cooperation with the Department of Engineering.) On account of mechanical difficulties with the storage room the test could not be started until November 27. The oxygen percentage steadily decreased, reaching 2 percent in three weeks, and thereafter the room atmosphere was maintained at 1 to 2.5 percent oxygen and around 8 percent carbon dioxide by periodical "washing" out of the latter and by infrequent partial ventilation to allow oxygen build-up. There is danger of anaerobic respiration, development of off-flavors, and death of apples under long-continued oxygen levels below 1 percent. The room was opened on March 17 and the apples removed.

Cortland had scalded slightly to severely even when wrapped in oiled paper, indicating that modified atmosphere storage is entirely unsuited to this variety. The Golden Delicious were in excellent condition with practically no shriveling, indicating that for this variety this type of storage may be especially suitable. The relative humidity remained high throughout the storage period and this is particularly important in successful storage of Golden Delicious. The McIntosh were variable, with condition good but quality only fair. They were already mature to slightly over-mature when the storage began to function properly late in December and, under these conditions, they came through better than expected.

On September 25, 1942, the room was again filled and at the time of writing (November 20) the storage appears to be functioning properly.

Nutrition of the High-bush Blueberry, Especially in Relation to Soil Reaction. (J. S. Bailey.) A mixture of equal parts by weight of sulfur and ferrous sulfate was found to be a good remedy for iron chlorosis. The amount required depends on the acidity and buffering action of the soil and condition of the plant.

Blueberry Culture. (J. S. Bailey.) Buds set in 1941 gave a small percentage of successes. Winter protection of the buds by sawdust was of little value because the buds failed to "take" before the sawdust was applied. Bushes were budded in 1942 at weekly intervals from July 25 to September 3 to observe the effect of time of budding. Although some buds have already died, the "take" seems to be much better than last year.

Four new varieties, Atlantic, Burlington, Weymouth, and No. 73, have recently been added to the collection, which includes all the improved varieties now in cultivation.

Preharvest Dropping of Apples. (L. Southwick.) Drop-control sprays and dusts were used on McIntosh, Duchess, and Wealthy.

With Duchess, which responded markedly to drop-control sprays in 1940, the results with dusts were disappointing although the three dusts used were partially effective. Two commercial materials applied as sprays were almost equally effective and significantly more effective than the dusts.

With Wealthy, which responded poorly to "hormone" sprays in 1940, dusts were relatively ineffective as was also one standard spray. With the other spray applications, the degree to which drop was controlled was correlated with the concentration of active chemical. These results support the conclusion reached previously that under Massachusetts conditions the stronger sprays are likely to be more effective. The added cost of more concentrated sprays may or may not prove profitable.

With McIntosh, results were variable, but in general dusts were more satisfactory than with Duchess or Wealthy. The three commercial dusts varied somewhat in apparent effectiveness but more than one season's tests are necessary to confirm that differential results are really due to "brand." Repeat

applications (four days after the initial applications) increased effectiveness and, in these cases, drop-control was substantially equal to that obtained with sprays. Applications followed in a few hours by rain were less effective. This was also true in the case of a spray which failed to dry before the onset of rain. In one instance, a second application four days after the first not only increased effectiveness but prolonged the duration of effect.

From these tests, it is evident that spray applications were, in general, more effective than dusts although the differences were not so significant but what they may be easily overcome when dust applications become more perfected. For best control of drop in Massachusetts orchards it may be necessary to increase concentrations somewhat.

Beach Plum Culture. (J. S. Bailey.) To gain a preliminary basis for procedure and to become more familiar with this fruit and its possibilities, a fertilizer experiment was started at East Sandwich in cooperation with Mr. William Foster and Dr. C. E. Cross.

A spraying experiment was also conducted consistent with the spray program outlined by Mr. Bertram Tomlinson in Special Cicrular No. 46. This program gave very poor control of plum gouger, the worst insect pest of the beach plum, but eliminated completely a gall maker which was present in great numbers on the leaves of unsprayed bushes adjacent to the sprayed plot.

Plum Pockets is one of the worst diseases of the beach plum. Plenty of infected fruits were found on older bushes surrounding the sprayed plot, but none on the sprayed plot. Brown Rot, another serious disease of the beach plum, and blights were fairly well controlled.

In cooperation with Dr. H. J. Franklin and Dr. C. E. Cross, a planting of improved selections was made at the Cranberry Station at East Wareham. These selections were supplied by Mr. J. M. Batchelor, plant explorer of the Soil Conservation Service, and are considered, by him, to be the best beach plums to be found anywhere along the east coast.

Other phases of the work are reported by the Departments of Botany and Horticultural Manufactures.

Ethylene Dichloride Emulsion. (J. S. Bailey.) Experiments to test ethylene dichloride emulsion for the control of peach tree borers were started in the fall of 1940 and continued through 1941 and 1942. Three cases of injury to trees were observed, all of which resulted from over-dosage or faulty application. No injury has been observed where applications were properly made.

Applications made September, October 1, and October 15, 1941, were very effective in controlling peach tree borers. Those made November 1 and November 15, 1941, were not so effective.

The Use of Peat in Planting Apple Trees. (L. Southwick.) In the 1940 Annual Report, a progress report was made on this experiment which began in the spring of 1939. It was reported at that time that, after two growing seasons, there was no significant difference in growth between the check and the treated trees. After two more years of growth, with scanty fertilization, the same conclusion holds.

Killing Woody Weed Plants. (J. S. Bailey and L. Southwick.) Ammonium sulfamate at three-fourth pound per gallon of water was very effective in killing chokecherries. The black cherry is much more resistant. Sprays of this material were used at several concentrations and the speed of killing of the leaves was proportional to the concentration. It is too early to determine the effectiveness of the various concentrations in destroying the whole plant.

On July 29, 1942, poison ivy in an apple orchard was thoroughly sprayed with

ammonium sulfamate at dosages of one-fourth and one-half pounds per gallon of water. By August 1 the younger leaves were considerably browned and dried out and the older leaves showed some injury. During the following week, most of the ivy appeared to be dead. The carry-over value of the treatment remains to be determined. Experience showed that care must be exercised not to get this poison ivy eradicant on apple trees.

Magnesium Deficiency in Massachusetts Apple Orchards. (L. Southwick.) In September 1939, medium to severe intervenal leaf scorch was observed on individual McIntosh trees in two experiment station orchards. These trees also showed excessive preharvest drop of fruit. A test for potassium showed a high level of this element in the leaves from affected trees. In August 1941, the same deficiency symptoms became prevalent in these and other orchards, particularly in a young orchard set in May 1939. In 1942, the trouble was evident in many commercial orchards. Other typical symptoms besides leaf scorch included occasional yellow banding and mottling and usually abnormally early leaf fall commencing near the bases of current shoot growths and progressing upwards. The symptoms suggested magnesium deficiency and chemical analyses of leaves in the late fall of 1941 tended to support this hypothesis. At that time, soil was collected from the young orchard mentioned above and Malling rootstocks were set in 2 and 3 gallon crocks and forced into growth in the greenhouse in February. Typical deficiency symptoms became evident in all pots where magnesium was not added and the trouble was most severe in the potassium-fertilized pots. Chemical analyses of the leaves showed low amounts of magnesium wherever deficiency symptoms were prevalent and high amounts where symptoms were not present.

In August 1942, leaf samples were obtained from many apple trees. Chemical analyses of unburned leaves from trees showing variable degrees of foliage scorch and leaf fall showed that there was consistent correlation between symptom severity and the magnesium and potassium leaf contents. Magnesium was always low and potassium always tended to be high in trees showing deficiency symptoms. Most of the affected orchards were on acid soils.

Just why the trouble has been more prevalent and severe in the past two years is not easy to explain although several factors may be significant. Increased use of potassium in recent years may have caused a build-up to such a point as to accentuate the need for magnesium. Increased use of mild sulfur sprays and sulfur dusts has tended to increase soil acidity. Weather conditions, particularly rainfall, may have influenced the amounts of magnesium available to trees. These are surmises only. Of course, it is probably true that magnesium deficiency in apple orchards is not new but that it had not been recognized as such.

Magnesium deficiencies may be overcome either through the use of adequate applications of high magnesium (dolomitic) limestone or, where quicker results are desired, by applying some soluble magnesium compound such as magnesium sulfate.

Temperature of Orchard Soils. (J. S. Bailey.) Thermographs were placed in the soil under two McIntosh trees in the Clark Orchard, one under a mulched tree, and the other under a tree growing in sod. The following observations were made:

1. The soil temperature under mulch was lower than that under sod from March to August; from August to late January the temperature under mulch was higher; from late January to March the soil temperature under sod and mulch was about the same and nearly constant.
2. Soil under sod warmed up faster in the spring and cooled off faster in the fall.

DEPARTMENT OF POULTRY HUSBANDRY

R. T. Parkhurst in Charge

Broodiness in Poultry. (F. A. Hays.) Results of crossing strains over a 10-year period confirm the hypothesis that two dominant complementary autosomal genes, A and C are necessary to produce the broody instinct in Rhode Island Red females. Extreme care in crossing strains is necessary to avoid bringing together these two genes.

The attempt is still being made to develop a non-broody strain of Rhode Island Reds through progeny testing. The major objective yet to be accomplished is to discover whether or not both genes A and C can be completely eliminated by this method.

A Genetic Study of Rhode Island Red Color. (F. A. Hays.) Two lines of exhibition-bred Rhode Island Reds are being developed: one selectively bred for early sexual maturity, and the other for late sexual maturity. Complete plumage color records are made on all birds, and females are trapnested for a full year to get their performance record. Feather samples are also taken at sexual maturity from all birds and these are being studied for pigment distribution.

Crosses between Rhode Island Reds and Buff Orpingtons indicate that the extension factor E for melanin pigment is not present, but that Buff Orpingtons are essentially the same as Rhode Island Reds in that the e factor permits the development of some black pigment in neck, wings, and tail. F_1 hybrids are intermediate in general plumage color, but the lipochrome pigment in skin, beak, and shanks is inhibited so that the color is white.

The Effectiveness of Selective Breeding in Reducing Mortality in Rhode Island Reds. Cooperative Project with the Regional Poultry Research Laboratory of East Lansing, Michigan, and the Department of Veterinary Science. (F. A. Hays.) Seven generations have been carried through to the age of 18 months to study the effectiveness of selective breeding in reducing mortality in one line and increasing mortality in another. The loss from cannibalism in the females of the low mortality line was double that in the high mortality line. Such losses distort the results, but there was no indication that selective breeding with small numbers is effective in reducing the mortality rate of males and females from the ordinary diseases and disorders.

Losses during this period were produced by a number of disorders but there were no acute outbreaks of disease. In many cases more than one disorder appeared in the same individual and the primary cause of death was not determined.

Genetic Laws Governing the Inheritance of High Fecundity in Domestic Fowl. (F. A. Hays and Ruby Sanborn.) At the present time particular attention is being given to the establishment of genetic uniformity in intensity of laying. Intensity is a complex character which has an important relation to egg size. Egg size has reached a satisfactory level, but intensity is still highly variable and there is considerable difficulty in combining large egg size with high intensity. The incidence and duration of winter pause have also received special attention. In other characters affecting egg production there is a satisfactory degree of uniformity in the flock.

A Study of Fertility Cycles in Males. (F. A. Hays.) In addition to the histological study of stages of spermatogenesis in males of different ages and at different seasons, still under way, attention has been given to fertility tests of males in natural matings throughout the summer. During this period the oldest male (36 months old) declined in fertility from 81 percent to 45 percent. The 24-

months-old male began with 100 percent fertility, declined to 74 percent in mid-June, but returned to 100 percent fertility in late July. The young male (12 months old) showed consistent fertility throughout the 10-week period, but his record was never equal to that of the 24-months-old male. On the female side, yearling hens were consistently higher in fertility than either old hens or pullets.

Miscellaneous Genetic Studies. (F. A. Hays.) Linkage studies between genes for shank feathering, comb form, and mottled ear lobes in Rhode Island Reds will soon be concluded. The dominant sex-linked gene has been eliminated so that stocks of crossbreds that carry only the autosomal gene E' are being developed. Progress is being made on a new method for separating the sexes in Rhode Island Red Chicks on the basis of down color. A gold-barred strain is being developed for auto-sexing chicks. The effect of ultra-violet irradiation on mutation rate is being studied. Selective breeding for abnormal sex-ratios is being carried on.

Alkaline Phosphates and Egg Shell Formation. (Marie S. Gutowska and R. T. Parkhurst, with the cooperation of E. M. Parrott and R. M. Verberg of the Chemistry Department.) Studies were conducted to throw more light on the question whether or not alkaline phosphatase is a factor in egg shell formation. It was found that:

1. The physiological mechanism of the deposition of calcium in the egg shell was independent of a local phosphatase activity factor in the shell gland (uterus) of the hen.
2. The phosphatase activity in the blood plasma of the laying hen seemed to be related to a definite genetic constitution of the hens—high productivity and good egg shell strength.
3. The deposition of calcium in the egg shell was based on a different mechanism than the calcification of the bones.
4. Phosphatase activity was very low in the shell gland, in the oviduct, and in the ova of the laying hens as well as in their bones at the time of shell formation. It was considerably higher in the blood plasma, coming within the lower range found in human blood.
5. The necessary transformation of the colloid compound containing calcium and phosphorus, and yielding calcium for the egg shell, appeared to take place in the blood itself; the shell gland acting, probably, only as an excretory organ for calcium.

Crab Meal as a Replacement for Fish Meal in the Laying and Breeding Rations. (Raymond T. Parkhurst and Emery J. Jefferson with C. R. Fellers of the Department of Horticultural Manufactures cooperating.) In further studies in which crab meal replaced fish meal on an equal-protein basis (4 pounds for 2.5 pounds) in the Massachusetts complete all-mash laying ration, corn dried distillers grains with solubles, corn distillers dried solubles, and fermentation solubles (with soybean oil meal) also replaced all the dried skimmilk in the ration.

The results confirmed previous conclusions that crab meal can replace all of the fish meal in the ration used, in which adjustment was made for the higher mineral content of the crab meal. Comparable egg production, egg weight, body weight, feed consumption, feed efficiency, egg quality, hatchability and chick quality were also obtained when the distillery and fermentation by-products replaced the dried skimmilk.

In the groups with Red-Rock crosses, the percentage hatchability of fertile eggs was higher for the rations containing skimmilk than for those containing distillers dried solubles, whether used with fish meal or crab meal and, in both cases, was higher for fish meal than for crab meal. For Rhode Island Reds, the

percentage hatchability of fertile eggs was higher for fish meal than for crab meal when used with distillers grains with solubles; but was higher for the crab meal when used with fermentation solubles and soybean oil meal.

Corn Dried Distillers' By-products in Laying Rations. (R. T. Parkhurst, C. R. Fellers, and J. W. Kuzmeski.) Complete or unsupplemented all-mash diets were fed to Rhode Island Red pullets in laying cages. All the dried skimmilk (2.5 percent) was replaced by an equal amount of dried distillers' by-products from mashes containing a high percentage of yellow corn. The by-products tested were the "screenings" or conventional light grains; the "grains," which were the grains with solubles or dark grains containing the residue (screenings) with which were dried the screened condensed stillage (solubles); and the "solubles", obtained by drying the stillage, after removal of the alcohol and "screenings."

The rations containing these by-products, each supplemented with meatscraps, gave as good production results as meatscraps and dried skimmilk, as indicated by percentage egg production, egg weights, body weight gains and egg quality. Mortality was low in all groups. Similar production results were obtained when fish meal replaced meatscraps as a supplement to "grains" and to "solubles". Hatchability was better when the "solubles" were fed. With either fish meal or meat scraps, "solubles" were comparable to milk in results obtained. With fish meal, "grains" also gave good hatchability.

Dried Cereal Grasses in Starting Rations. (R. T. Parkhurst, J. H. Vondell, and J. W. Kuzmeski.) Dried cereal grasses at levels of 1.25 and 2.5 percent adequately replaced dehydrated alfalfa meal at a 5 percent level in a meatscrap basal ration in which the vitamin D was obtained from D-activated animal sterol. In a similar comparison involving the 1942 (revised) New England College starter, equally good results were obtained with a low cost ration containing 15 percent soybean oil meal, dry vitamin D, and both dried cereal grasses and alfalfa meal, provided both fish meal and meatscraps were used. Results were not satisfactory when meatscraps were the only animal protein concentrate included in the ration.

DEPARTMENT OF VETERINARY SCIENCE

J. B. Lentz in Charge

Poultry Disease Control Service. (H. Van Roekel, K. L. Bullis, O. S. Flint, and M. K. Clarke.)

1. *Pullorum Disease Eradication.* During the 1941-42 testing season 366 chicken flocks and 31 turkey flocks were tested for pullorum disease. The results from this service are reported in a separate bulletin issued for that purpose.

2. *Diagnostic Service.* A total of 2,180 specimens in 498 consignments were examined. Personal delivery of specimens was made in 252 cases. The specimens may be classified as follows: 1,932 chickens, 190 turkeys, 11 foxes, 9 mink, 8 each of goat feces and pigeons, 4 each of pheasants and rabbits, 3 each of canine feces and geese, 2 each of dogs and quail, and 1 each of equine feces, feed, parrakeet, and sheep.

It is encouraging to note that avian tuberculosis and fowl typhoid were not encountered during the year. The former has not been widespread in recent years, but fowl typhoid began to reach serious proportions until 1939, when educational activities by the County Extension Services and the Massachusetts Division of Livestock Disease Control were apparently effective in checking further

spread. Pullorum disease is rarely encountered in chicks where owners have adopted effective measures for the eradication and prevention of this disease. Twelve new foci of fowl cholera infection were identified during the year. Fowl cholera has been found on 53 premises during the past 10 years. This disease continues to become more widespread and of greater economic importance. Listerellosis was identified in one chicken, but apparently was not a source of great trouble in the flock in which it was encountered. The 69 tumors encountered were classified on the basis of gross examination as lymphocytoma 35, embryonal nephroma 9, myelocytoma 7, fibrosarcoma 5, hemangioma 4, fibroma 2, not identified 2, hematoma 1, leiomyoma 1, and myxoma 1.

The 190 turkeys were received in 48 consignments. The diseases encountered most frequently were coccidiosis, paratyphoid, ulcerative enteritis, and enterohepatitis. Four cases of pullorum disease were poults shipped in from outside of the State. Swine erysipelas was detected in September in two flocks which were being reared in confinement. Limited observations suggest that this infection is apt to be encountered earlier in the season in birds reared in confinement than in birds reared on range; also that such an outbreak may be controlled by letting the birds out on range. This reduces direct contact between birds and stops much of the feather picking.

3. *Flock Mortality Studies.* Morbid and dead birds from the flock maintained at the College for genetic studies have been examined to determine the causes of mortality and to furnish information for experiments in genetics. This is a continuation of work similar to that conducted in former years. During the fiscal year, 340 birds were examined. Since these represent birds hatched over a period of five years, major emphasis is placed on the group which finished its first laying year during the past fiscal year. From the birds hatched in the spring of 1941, a total of 331, representing 242 females and 89 males, have been examined. No extensive outbreak of any particular disease was noted during the year, but the recognition of 13 cases of aspergillosis was unusual. Fowl paralysis was noted in an increased number of birds, despite efforts to effect a reduction through elimination of families showing a high incidence of the disease. Over three-fourths of the cases of fowl paralysis noted were in birds which had not reached sexual maturity. Fowl paralysis was noted more frequently than any other disease. Other conditions noted in order of frequency were kidney disorders, tumors, reproductive disorders, and cannibalism. Pathological conditions in birds more than 18 months of age were quite similar to those in the younger birds, except that the percentages of leiomyoma and carcinoma increased markedly.

4. *Salmonella Types Isolated.* Paratyphoid organisms isolated from diseased specimens were identified as to type. A total of 15 strains was recovered from consignments received from 10 different flocks. Twelve strains were *S. typhi-murium*, two were *S. newport*, and one was *S. derby*. The *S. typhi-murium* strains were isolated from two pigeons and ten turkeys (five poults and five mature birds). The *S. newport* and *S. derby* strains were recovered from poults. In one instance *S. typhi-murium* and *S. derby* were isolated from the same flock, but the stock originated from two different sources which may account for the presence of the two types.

We are greatly indebted to Dr. Philip Edwards, Department of Animal Pathology, University of Kentucky, Lexington, Kentucky, who identified these strains as to type.

5. *Avian Encephalomyelitis.* Duirng the past year studies of avian encephalomyelitis were continued. Serial passage of this virus in young chicks has reached the 128th transfer. No perceptible change in the nature of the virus has been

observed. Chicks hatched from eggs laid by laboratory breeding stock revealed evidence of avian encephalomyelitis at hatching time. This observation further substantiates previous findings at this laboratory that this infection may be egg-borne.

6. *Infectious Bronchitis.* During the past year investigations in the control of infectious bronchitis were continued with the cooperation of the Extension Service and the Massachusetts Division of Livestock Disease Control. The 14 flocks inoculated with a laboratory strain of live infectious bronchitis virus in the summer of 1941 passed through the laying season without contracting the disease. In two instances evidence of respiratory infection was observed, but infectious bronchitis was not definitely diagnosed.

The results of these field investigations were received with great enthusiasm by other flock owners whose flocks had experienced this disease. During 1942 the program was extended to additional flocks in which the infection had previously been observed. Susceptible birds were inoculated or exposed to infection before reaching sexual maturity. In most instances post-inoculation reactions were favorable. However, it was noted that concomitant infections or diseases and climatic and management factors play a definite role in the response of the flock to infectious bronchitis virus. Mature birds which were regarded as immune to the infection due to previous exposure failed in every instance to contract the disease from the inoculated young stock. The results of the field trials appear encouraging, but before a practical control program is inaugurated further critical tests should be conducted.

Investigations have also been continued to develop a reliable method of detecting birds that have been exposed to infectious bronchitis infection. Such a method will serve as a guide in using this virus only in flocks that have had the disease.

7. *Farm Department Brucellosis Control and Eradication.* The laboratory cooperated in this work by testing 639 bovine blood samples by the standard tube agglutination method.

Studies of Neoplastic and Neoplastic-like Diseases. (Carl Olson, Jr.) Progress under this study was interrupted by Dr. Olson's enlistment in military service and therefore no conclusive report is possible at this time.

WALTHAM FIELD STATION
Waltham, Massachusetts
Ray M. Koon, in Charge

The members of the research staff of the Waltham Field Station are assigned to the unit by the Departments of Botany, Entomology, Floriculture, Horticulture, and Vegetable Gardening. Reports of these departments give results of investigations conducted at this station.

Soil Testing Service. Testing soil for commercial vegetable growers, mushroom growers, florists, nurserymen, greenkeepers, arborists, vendors of loam, and home gardeners has long been regarded as an important service which the Field Station has rendered. More recently this program has been extended to include service to the State Department of Public Works, the Metropolitan District Commission, Works Project Administration, U. S. Army Engineers, and town and city administrations. There is no doubt that this effort is effective, particularly when the soil test is followed by a personal interview between the client and the technician. The total number of soil samples tested in 1942 was 6134.

Field Day. Because of the shortage of gasoline and tires, and the lack of farm machinery for demonstration purposes, this annual meeting, which would have been the twenty-fourth, was not observed. Special groups and individuals, however, interested in certain particular experiments and trials visited the Station at opportune times. Among them were the New England Carnation Growers Association, Boston Market Gardeners Association, Greenkeepers Club of New England, Society of American Florists and Ornamental Horticulturists, Massachusetts Fruit Growers Association, U.S.D.A. Club, New England Seedsmen's Association, and the New York–New England Fruit Spray Specialists.

PUBLICATIONS

Bulletins

388 Annual Report for the Fiscal Year Ending November 30, 1941. 108 pp. illus. February 1942.

The main purpose of this report is to provide an opportunity for presenting in published form, recent results from experimentation in fields or on projects where progress has not been such as to justify the general and definite conclusions necessary to meet the requirements of bulletin or journal.

389 Production and Prices of Milk in the Springfield–Holyoke–Chicopee Milkshed in 1935. By Alfred A. Brown and Mabelle Booth. 32 pp. illus. February 1942.

A comprehensive understanding of the productive organization and the marketing disposal facilities of the fluid milk industry is a necessary basis for sound marketing regulation. To this end, the investigation reported here was undertaken.

390 The Composition and Nutritive Value of Potatoes with Special Emphasis on Vitamin C. By William B. Esselen, Jr., Mary E. Lyons, and Carl R. Fellers. 19 pp. March 1942.

Potatoes enjoy a prominent position in the American diet. It is the purpose of this study to evaluate the nutritive properties of this popular vegetable, with special emphasis on the value of the cooked potato as a source of vitamin C.

391 A Survey and Study of Spontaneous Neoplastic Diseases in Chickens. By Carl Oslon, Jr., and K. L. Bullis. 56 pp. illus. April 1942.

Neoplastic diseases (tumors) cause much loss to the poultry industry. This collection of cases of neoplasia gives information of the characteristics and relative incidence of the different types.

392 Blooming Dates of Some Selected Hardy Perennials. By Harold S. Tiffany. 55 pp. April 1942.

A flower lover's ambition is to have some blooms available in the garden at all times during the growing season. This bulletin should be of service in the selection of perennials for that purpose.

393 Bay State, A Red Forcing Tomato Bred for Resistance to Leaf Mold. By E. F. Guba. 8 pp. illus. June 1942.

Leaf mold is a devastating disease of tomato in greenhouses and its control is difficult and expensive. This bulletin describes a new greenhouse tomato which combines resistance to certain strains of the fungus with desirable commercial fruit type.

394 The Control of Damping-off of Vegetables by Formaldehyde and Other Chemicals. By W. L. Doran, E. F. Guba, and C. J. Gilgut. 20 pp. June 1942.

Damping-off is one of the most serious problems of the vegetable grower, and the results here reported should provide safer and more effective control of the disease in hotbeds and greenhouses.

395 Preparation and Use of Artificial Manures. By Karol J. Kucinski. 12 pp. illus. July 1942.

The real or assumed dependence of crop production upon animal manures has encouraged this attempt to provide an artificial substitute.

396 Breeding Rhode Island Reds for Rapid Feathering. By F. A. Hays and Ruby Sanborn. 24 pp. illus. September 1942.

Rapid chick feathering, particularly over the back region, is a very valuable character in general purpose fowls. This study was carried on over a long period to discover a reliable method for fixing this character in Rhode Island Reds.

397 A Civilian Program for Tree Protection. By Malcolm A. McKenzie. 32 pp. illus. December 1942.

Public appreciation of shade trees in Massachusetts is evidenced by the extensive and varied planting throughout the State. This bulletin, prepared primarily to promote municipal tree management, also suggests methods of tree care in general.

Control Bulletins

112 Twenty-second Annual Report of Pullorum Disease Eradication in Massachusetts. By the Poultry Disease Control Laboratory. 11 pp. June 1942.

113 Inspection of Commercial Feedstuffs. By Philip H. Smith. 25 pp. September 1942.

114 Inspection of Commercial Fertilizers and Agricultural Lime Products. By Fertilizer Control Service Staff. 48 pp. October 1942.

115 Seed Inspection. By F. A. McLaughlin. 94 pp. December 1942.

Meteorological Bulletins

637-648, inclusive. Monthly reports giving daily weather records, together with monthly and annual summaries. By C. I. Gunness. 4 pp. each.

Reports of Investigations in Journals

385 The Effect of Storage on Carbohydrates of the Ebenezer Onion. By Emmett Bennett. Amer. Soc. Hort. Sci. Proc. 39:293-294. 1941.

399 Scoring Baked Potatoes for Texture. By Monroe E. Freeman. Food Res. 6 (6):595-598. 1941.

401 A Study of Neoplastic Disease in a Flock of Chickens. By Carl Olson, Jr. Amer. Jour. Vet. Res. 3(6):111-116. 1942.

403 Report on Soluble Chlorine in Feeding Stuffs. By John W. Kuzmeski. Assoc. Off. Agr. Chem. Jour. 25 (4):870-874. 1942.

406 Vitamin Content of Green Snap Beans. Influence of Freezing, Canning, and Dehydration on the Content of Thiamin, Riboflavin, and Ascorbic Acid. By Kenneth T. Farrell and Carl R. Fellers. Food Res. 7 (3):171-177. 1942.

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415 A Device for Marking Fields on Microscope Slides. By Carl Olson, Jr. Jour. Lab. and Clin. Med. 27 (7):939-940. 1942.

417 The Significance of Tannic Substances and Theobromine in Chocolate Milk. By William S. Mueller. Jour. Dairy Sci. 25 (3):221-230. 1942.

418 Experimental Autoecism and Other Biological Studies of a Gall-Forming Peridermium on Northern Hard Pines. By Malcolm A. McKenzie. Phytopathology 32 (9):785-798. 1942.

419 Report on Zinc. By E. B. Holland and W. S. Ritchie. Assoc. Off. Agr. Chem. Jour. 25 (2):393-394. 1942.

421 Maintaining Fertility Levels in Massachusetts Pastures. By W. G. Colby. Soil Sci. Soc. Amer. Proc. 6 (1941):281-284. 1942.

422 The Inheritance of Blossom Type and Blossom Size in the Peach. By J. S. Bailey and A. P. French. Amer. Soc. Hort. Sci. Proc. 40:248-250. 1942.

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426 Trunk Diameters of Young Apple Trees on Clonal Stocks. By J. K. Shaw. Amer. Soc. Hort. Sci. Proc. 40:269-271. 1942.

427 An Improved Orange Juice Concentrate. By A. Sedky, C. R. Fellers, and W. B. Esselen, Jr. Fruit. Prod. Jour. 21 (5):136-138. 1942.

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429 The Availability of the Iron of Cocoa and of Iron-Fortified Cocoa Mixtures. By Faye Kinder, W. S. Mueller, and Helen S. Mitchell. Jour. Dairy Sci. 25 (5):401-408. 1942.

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